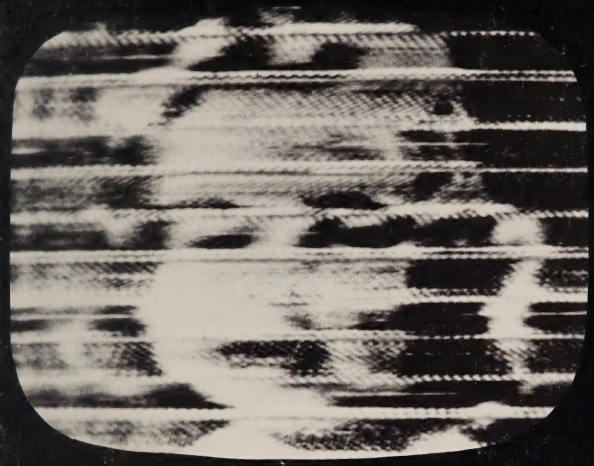
The Coney Island Baby Laboratory • Henry Ford's Terrible Flaw

AMERICAN HERITAGE OF
Invention & Technology

FALL 1994 • VOLUME 10/NUMBER 2



The Race to Video

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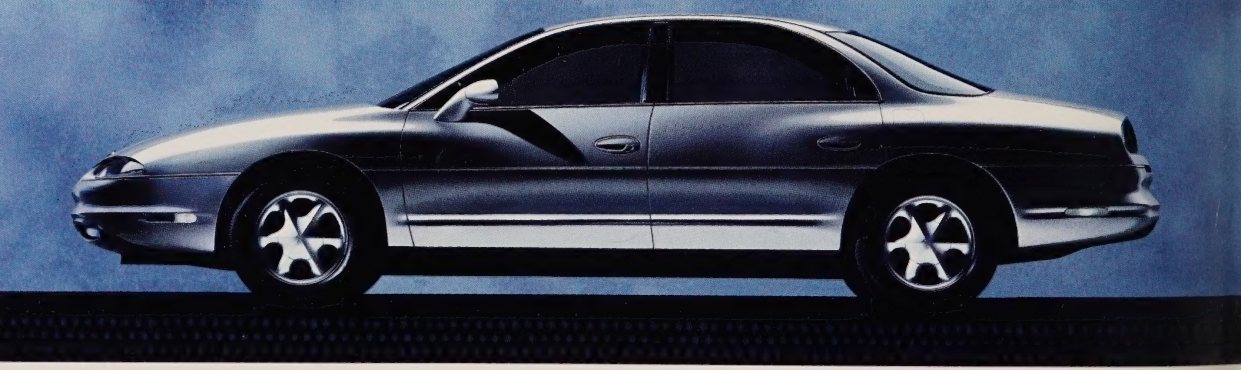
Pardon us while we annihilate a few old notions.



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AMERICAN HERITAGE OF INVENTION & TECHNOLOGY (ISSN: 8756-7296) is published quarterly by American Heritage, a division of Forbes Inc., Forbes Building, 60 Fifth Avenue, New York, NY 10011. Correspondence about subscriptions should be addressed to American Heritage of Invention & Technology, Subscription Office, P.O. Box 5335, Harlan, IA 51593, or call 1-800-627-4022. Annual subscriptions: $15 for one year in the United States and its possessions; two years, $22.50; for foreign surface mail, add $3 per year.

Second-class postage paid at New York, N.Y., and additional mailing offices. Postmaster: Please send address changes to American Heritage of Invention & Technology, Subscription Dept., Forbes Building, 60 Fifth Avenue, New York, NY 10011.

This magazine considers but assumes no responsibility for unsolicited materials; these require return postage. All editorial correspondence should be addressed to AMERICAN HERITAGE OF INVENTION & TECHNOLOGY, Forbes Building, 60 Fifth Avenue, New York, NY 10011.

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GM

MARK OF EXCELLENCE

AMERICAN HERITAGE OF
Invention & Technology
FALL 1994 • VOLUME 10/NUMBER 2

ALL: AMPEX CORPORATION

THE COVER: In the early 1950s television networks wanted to adapt the still-young technology of audiotape recording to the vastly more complex video signal. RCA took an early lead, but in the end a half-dozen men at a virtually unheard-of California company won the day. For more on the great videotape race, see page 52.

2 LETTERS

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On the Chesapeake Bay's Eastern Shore, a solitary craftsman tries to keep an outdated industry alive with seventy-year-old machinery.

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An eminent scholar analyzes the place of drag racing in American culture, and several other *I&T* authors also publish books.

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Some medical research is supported by government grants or charity, but incubators were developed with a different source of funding: two-bit tickets to a Coney Island sideshow.

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How success spoiled the early auto industry's most creative innovator.

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When the 25th U.S. Infantry Bicycle Corps rode from Missoula, Montana, to St. Louis, they faced a lot more than the occasional pothole.

52 THE RACE TO VIDEO *by Stewart Wolpin*
The first practical videotape recorder resulted from a three-way, five-year engineering horserace.

64 POSTFIX *by Lamont Wood*
The Datapoint 2200 was designed as a simple terminal, but users turned it into the world's first desktop computer.

The Fly

"The History of the Zipper?" (by Robert Friedel, Summer 1994) brought to mind my first experience with a zipper, just before the summer of 1940. I opened a law office in 1938, and in the spring of 1940 I bought a new suit, with a zipper, for $59.50. Connecticut's blue laws forbade the sale of liquor after 9:00 P.M. on Sunday, and to attract diners, the Seven Gables in Milford, the premier nightclub in the area, had a Sunday dinner from six to nine for one dollar. Still a bachelor, I invited a recent Smith College graduate for an afternoon ride in my new used Plymouth, followed by dinner and dancing at the Seven Gables.

In the late afternoon a car sped by us and slammed into a tree on a curve in the highway. My date and I helped to extricate four Yale students from their wrecked car (the struck tree bears a scar to this day). Eventually we arrived at the Seven Gables and dined and danced to the rhythms of a big band led by Frankie Carle, the composer of "Sunrise Serenade." I went to the men's room wearing my new suit. I pulled the zipper down. All the king's horses and all the king's men couldn't get the zipper back up again, even with soap or pencil lead applied to it. The men's room attendant gave me two safety pins. The next day I had the zipper removed and went back to buttons.

Harold B. Yudkin
Derby, Conn.

It surprised me that Robert Friedel's article did not mention the Talon slide fastener. The Talon name was stamped on my memory at the early and impressionable age of five, in 1929, when my mother and I made a number of trips from Ohio to Meadville, Pennsylvania, to visit my sister there. I became aware that Talon, at least through the thirties, never used the word *zipper*. Since Mr. Friedel carries his narrative up to 1939, I am curious as to Talon's place in the picture.

Robert C. Tompkins
Towson, Md.

Robert Friedel replies: Talon was indeed the most famous name in zippers for generations of Americans. The Hookless Fastener Company adopted the name for its product in 1928, when competitors began to chip away at Hookless's hard-won markets. *Talon* also had the virtue of fitting easily on the pull-tab of the zipper. In 1937 the corporate name was changed to Talon, Inc. The word *zipper* was introduced when B. F. Goodrich began selling its galoshes by that name in 1923; the name, quickly extended to the fastener, proved far more durably popular than the boots themselves.

Talon is today part of a British conglomerate, Coats Viyella PLC, but today's zippers are more likely to be marked YKK, the initials of the world's biggest manufacturer of zippers, a Japanese giant that as of 1991 had 171 plants and offices in forty-two countries. YKK began challenging Talon for primacy in the American market in the 1970s, and today its Macon, Georgia, factory alone turns out several million zippers every day.

How to Freeze

I read with delight Rudi Volti's article "How We Got Frozen Food" (Spring 1994). In 1949 I was offered a summer job by the International Harvester Company as a home economist to travel around a specific district teaching people how to preserve foods through freezing and properly care for commercially frozen products. This turned into a year-round position, and I left teaching and became committed to corporate home economics. Later I became regional home economist of the northwest territory for the company, supervising seventeen or eighteen district home economists. We had frozen-food demonstrations in dealers' showrooms, schools, church basements, city auditoriums—almost any place with space to seat a crowd comfortably and access to a range or a hot plate. Many, many funny episodes occurred, but overall we gave people necessary instructions and played a meaningful part in making frozen-food storage available anywhere.

Geraldine Jurisson
Elgin, Ill.

I was a member of a crew that installed a sprinkler system at General Sea Foods in Gloucester, Massachusetts, in 1947. Most of the time I was there they were processing a "junk" fish under four different brand names. The only difference among them was that the Birds Eye brand had to be packed a certain way. The fish was just called red fish and had usually been thrown out, since it had no market around here. Someone renamed it ocean perch and shipped it frozen to the Midwest where they could not stock it fast enough. By 1947 it was even showing up in our neck of the woods, and local fishermen had a new product they could sell thanks to the flash-freezing process.

Clement J. Hogan
Somerville, Mass.

Plane Speaking

Concerning the article "How They Got Planes on Ships" (by T. A. Heppenheimer, Summer 1994), the caption for the opening photograph is correct—but not wholly correct. Half the airplanes in the photo are not Dauntless dive bombers (made by Douglas) but are Hellcats plus one Avenger (both made by Grumman).

Warren M. Lane
Greenlawn, N.Y.

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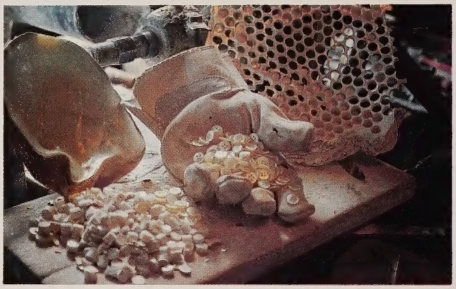
They're Still There

BY FREDERICK ALLEN

Last of the Pearl Buttons

"COME ON IN OUT OF THE MOSQUITOES," SAYS DANIEL Martinek. He is standing next to a shotgun shack beside a stand of tall loblolly pines. "This is where I spent every day for thirty-five years. It looks like it's over now." Inside, line shafting runs down the middle of the single long room; muskrat hangers are suspended along either side. Connected to the shafting are a dozen small machines used in the manufacture of mother-of-pearl buttons. White pearl dust covers everything. We are on Elliott Island, one of the remotest spots on the Eastern Shore of the Chesapeake Bay. Here Dan Martinek is watching an industry vanish.

"It's four years since we had seven or eight people working here," he says. "But we were doing good until last year. Then it went dead, and I mean dead, dead, dead. It's been bad before, but never this bad." He hasn't had an order in months. Mother-of-pearl buttons cost at least three times as much as plastic ones, are more fragile, and are indistinguishable except to an expert.



Shells punched and unpunched, blanks, and the product.

"We moved here in 1950 from Little Ferry, New Jersey," he says. "I was seven. Daddy had a mink farm there and made buttons too. The doctor told him he was sick and had to move. Daddy ran out of money, so he built this shop, bringing down machines he'd had in New Jersey. He says now if he had it to do over again, he never would.

"These machines are all maybe seventy years old, maybe older. There are two other companies left in America that make pearl buttons, or were making them, and we've swapped these with them sometimes. Let me show you how they work." He flips a switch, and the overhead shafting whirs into motion. "Now, when you get shells, after you grind the hinges off, you set a shell here and punch out the button blanks with this machine. Each hole you punch, that's eight cents, so you try to get every one." As he drills into a shell, he says, "I love that smell." It is an acrid, familiar smell—the same hot calcium odor as from a dentist's drill.

The next step is pouring the blanks into a sieve to shake off dust. Then he drops them onto a grading machine—basically two nearly parallel pipes closer together at the top end. Buttons roll down between the pipes and fall into several boxes according to thickness. "The first box you throw away or save them for inlays—for instance, those little markers on the rims of pool tables. We used to have a good business in them. The thickest blanks you split, by this saw over here. Then you'll end up with sixteen cents instead of eight. You'd pick up a nickel on the ground, right? Well, this is better. Only some that are too thin I have to split by hand." He shows me how, with a hammer and a blade.

"Then with this grinding wheel here you grind the back off—the dark of the shell. You flatten the faces between two grinding stones, and you have a perfect blank. Now you need to make the faces and the holes. We used to have seven women here drilling holes, and eighty gross a day was good. Then we got our one new machine. It cost $5,000, and it was a gamble, but it saved the business for fifteen years. You just turn it on and lay the buttons onto it, one by one, one a second all day long, and you've done more than a hundred gross in a day. That saved us until something happened. Those buttons you're wearing"—he points at my standard-issue Brooks Brothers shirt, whose buttons do look just like his—"those are sixteen-line English four-hole polyester. They cost two cents apiece. We can't compete. And the shells aren't as good as they used to be either."

He pulls a corncob pipe out of his pocket, loads and lights it, and goes on. "Once you've got a couple of cans of buttons, maybe two hundred gross, you put them in a barrel with pumice and roll them for two hours. That cuts off all your blemishes. Then you wash them and put them in a polish barrel." After that they go through sulfuric acid and a hydrogen peroxide bleach. "Then you put them to dry in this baby." It is a custom-rigged clothes dryer.

The next-to-final step is a toss in corncob dust and finishing cream to add luster and then in corncob dust alone to remove the cream. "Then comes the hard part: sorting them." He leads me to a conveyor-belt setup that lets buttons pass one side up and then the other. "You have to look at them and take out all the yellow ones. You couldn't give away yellow buttons, so you dye them gray, for ladies' shirts and so on."

He switches off the drive machinery and smiles at it and says, "That's what I listened to for thirty-five years, that hum. I miss it. I do. I just loved to come here in the wintertime, when the weather's cold, and turn the furnace up to sixty-five and prop my feet on the radiator and work. There's nothing like it. I never missed a day. Even if I was sick, I'd sit and punch blanks. But it's over with."

He gestures toward the boxes of blanks awaiting orders that will not come. "All these I'll put out on the driveways here, just so people will remember me after I'm gone." ★

BOTH PAGES: DENNIS BRACK/BLACK STAR

Daniel Martinek retrieves blanks from a grinding wheel that removes their rough backs after their size is determined by the sorter behind his back.

BY FREDERIC D. SCHWARZ

Post Haste

An eminent scholar ponders the social ramifications and historical significance of hot rods, funny cars, top fuelers, and other dragsters.

BALTIMORE, MD.: When Jacques Barzun wrote, "Whoever wants to know the heart and mind of America had better learn baseball," in 1954, he inspired today's pastoral school of baseball writing, in which every pop fly is an evocation of our country's bucolic heritage. While it's doubtful that the bleacher bums at Wrigley Field have any such thing in mind when they turn out to cheer the Cubs, Mr. Barzun does have a point: In its journey from a middle-class weekend pastime played in country fields to a multibillion-dollar business played in concrete-and-AstroTurf stadiums, baseball encapsulates our country's development and says something fundamental about the American character.

Of course, the same could be said for any sport—football, basketball, even badminton or water polo if you try hard enough. Yet some objects of study are more informative than others. While baseball does recall our nation's rustic past, that era is remote to most modern Americans. The best way to get a handle on our automobile-centered suburban post–World War II culture may be by examining an equally rich but newer sport, drag racing. No wonder, then, that Robert C. Post of the Smithsonian Institution has written *High Performance: The Culture and Technology of Drag Racing 1950–1990* (Johns Hopkins, $34.95), the first complete scholarly analysis of America's compulsion to travel a quarter-mile in ever-smaller bits of time.

Post, a hot rodder himself in his youth, explains how the spirit of 1940s teen-agers matching hopped-up Ford Model A's manages to live on in the days of television and corporate sponsorship. Since it was first organized and regulated, drag racing has been shaped by conflicts between different factions with different goals. In the early days Californians and "Easterners" (meaning anyone between Arizona and the Atlantic) struggled for control. Schisms developed between rich playboy types and back-yard tinkerers, leading to complaints that "big money" was corrupting the amateur nature of the sport—even though no more than half a dozen drag racers made more than they spent at any time during the 1950s and 1960s. Other conflicts included drivers contending with promoters over gate receipts and, later, women struggling with the male power structure—first simply to be allowed to compete, then to be accepted as equals.

Post shows how the technology of the cars developed alongside the organization of the sport and how these two halves of the story influenced each other. For example, the National Hot Rod Association (NHRA) banned the use of "fuel"—nitromethane—in dragsters from 1957 to 1963, ostensibly because it was unsafe. The real reason, Post suggests, was that fuel was much more expensive than gasoline, and Wally Parks, the NHRA's president, feared its superior power would tilt the balance away from those with mechanical ingenuity and toward those with deep pockets. The policy ultimately failed because non-NHRA events with fuel-powered dragsters proved too lucrative to ignore.

Three decades later a dispute over computer-controlled transmissions ended in a ban on virtually all use of artificial intelligence. Here again, the idea was to keep drag racing in the hands of car builders and drivers, instead of chip designers. Today's software engineers could automate race driving as much as they have aviation, but since the main goal of drag racing is excitement, not safety, such a seemingly obvious extension would in fact be counterproductive.

BARRON STOREY

With his past articles in *Invention & Technology* ("In Praise of Top Fuelers," Spring 1986; "The Machines of Nowhere," Spring 1992) and elsewhere, and now his book, Post has become to drag racing what Roger Angell is to baseball, Norman Maclean is to fishing, or Joyce Carol Oates is to boxing. Only occasionally does the narrative slip into automotive lyricism, and the few list-every-name paragraphs, like the Bible's sequences of "begats," can easily be skipped by the less devout.

In his thirteen years as editor of *Technology & Culture*, the Society for the History of Technology's journal, Post gained a reputation for being at home in any area of the discipline, no matter how abstruse. In *High Performance* he delves into one topic intensely, skillfully elucidating its connections with other areas of study. The resulting performance is high indeed, and it shows how much struggle and refinement—technical, social, economic, and many other kinds—goes into four seconds of noise and smoke and speed.

EDITORS' BOOKSHELF: Several other *Invention & Technology* contributors have recently published books:

Michael Brian Schiffer, author of "Postfix" columns on portable radios (Summer 1992) and electric motors (Winter 1994 and Summer 1994), has written *Taking Charge: The Electric Automobile in America* (Smithsonian Institution Press, $24.00). Schiffer details the vicissitudes of electric cars between the mid-1890s and the early 1920s, finding that at the turn of the century they were on an even footing with cars powered by steam and gasoline. Sales dropped as the new century wore on but enjoyed a brief revival starting around 1907, when improvements in cars and batteries made electrics briefly competitive. What Schiffer calls the Classic Age ended in the early teens, however, when the self-starter (an electrical device, ironically enough) eliminated cranking on gasoline cars and made them irresistibly superior for most buyers.

Early electric cars had important advantages over internal combustion: they were quieter, cleaner, and easier to start and operate, did not smell, and required no transmission. Balanced against these virtues were equally major flaws: the batteries were heavy and needed constant maintenance and recharging, and the cars were slow, expensive, and limited to ranges of a hundred miles or less. Recreational touring and rural use were out of the question, but Schiffer suggests that electrics could have established a niche market in urban areas for uses requiring frequent short trips—as taxis and delivery trucks, and by doctors and other professionals, salesmen, and socialites making their rounds.

Near the end he optimistically asserts that "if middle-class women had enjoyed greater economic independence, the electric car in the teens might have found a market of millions," instead of seeing its sales peak at an annual figure of 6,500 units—about three days' production for Ford in 1916. Whether you buy that conclusion or not, the book is a valuable reminder of how divergent technologies struggled for supremacy in the automobile's early days and of the obstacles that electric vehicles continue to face today.

James E. Tomayko ("The Airplane as Computer Peripheral," Winter 1992) has written *Computers in Space: Journeys With NASA* (Alpha Books, $20.00 paperback), a history of the use of computers to guide space flight. The author, a pilot and professor of software engineering, manages to transcend the inherently stultifying nature of computer writing, with its acronyms and flow charts; he discusses such antique computers as the IBM 704, RCA 110A, and Univac 1230 with the same love that drag-racing enthusiasts like Bob Post apply to a '32 Ford coupe.

Tomayko tells of the late-1950s post-*Sputnik* rush to develop spacecraft, when computers were so slow that displays at Mission Control might lag two seconds behind real life (during which a rocket could travel ten miles). The first on-board computer, in the 1962 Gemini capsule, had to fit in a slot nineteen by fifteen by thirteen inches —this in an age when a typical research computer installation might take up all of a large room. The backup system for this computer consisted of a second astronaut checking calculations with a pencil and paper.

Working conditions for programmers were quite primitive by today's standards. Into the 1970s some software designers had to test their work by sending a batch of punch cards by courier to a building a mile away. They generally managed one run a day. Not until 1976 was a direct link installed. Apollo saw the first use of integrated circuits, leading to the modern space shuttle, which puts such great faith in its computer guidance system that no manual override is possible. Tomayko gives the whole story clearly and smoothly, with enough detail to satisfy chipheads and enough explanation to enlighten the clueless.

And finally, readers who enjoyed Robert Friedel's story on zippers in our last issue will welcome his book-length treatment of the subject, *The Zipper: An Exploration in Novelty* (W. W. Norton, $23.00). Friedel takes the zipper story up to the present day, poignantly describing how foreign competition caused Talon, Inc. (successor to the Hookless Fastener Company), to pull out of its long-time home in Meadville, Pennsylvania. He analyzes the literary, artistic, and symbolic aspects of zippers and even gives the lyrics to a company song ("Zipper Boots, Oh Zipper Boots," sung to the tune of "Maryland, My Maryland") that was regrettably omitted from his *Invention & Technology* article. Friedel's book is a must for anyone interested in seeing what's behind the zipper. ★

The Golden

Iron was the miracle material of the nineteenth century—abundant, cheap, and extremely useful. It was perfect for jobs requiring great strength in proportion to weight: cylinders for pumps and steam engines; boats and barges for canals; beams and columns for mill buildings; and, eventually, bridges. Several thousand iron bridges were built in America between 1840 (when iron began to replace wood and stone) and 1880 (when it was in turn being superseded by steel); some six dozen survive.

These bridges used cast iron for compression members and wrought iron for tension members. Steel at the time was prohibitively expensive; wrought iron cost twice as much as cast iron but resisted tension (stretching) so much better that it was worth the expense for certain parts of a bridge. Wood was still often the cheapest material for much of the century, but it grew increasingly obsolete. Iron was the modern wonder—strong, affordable, mass-producible, portable, fire-resistant, and capable of being shaped into the loveliest designs.

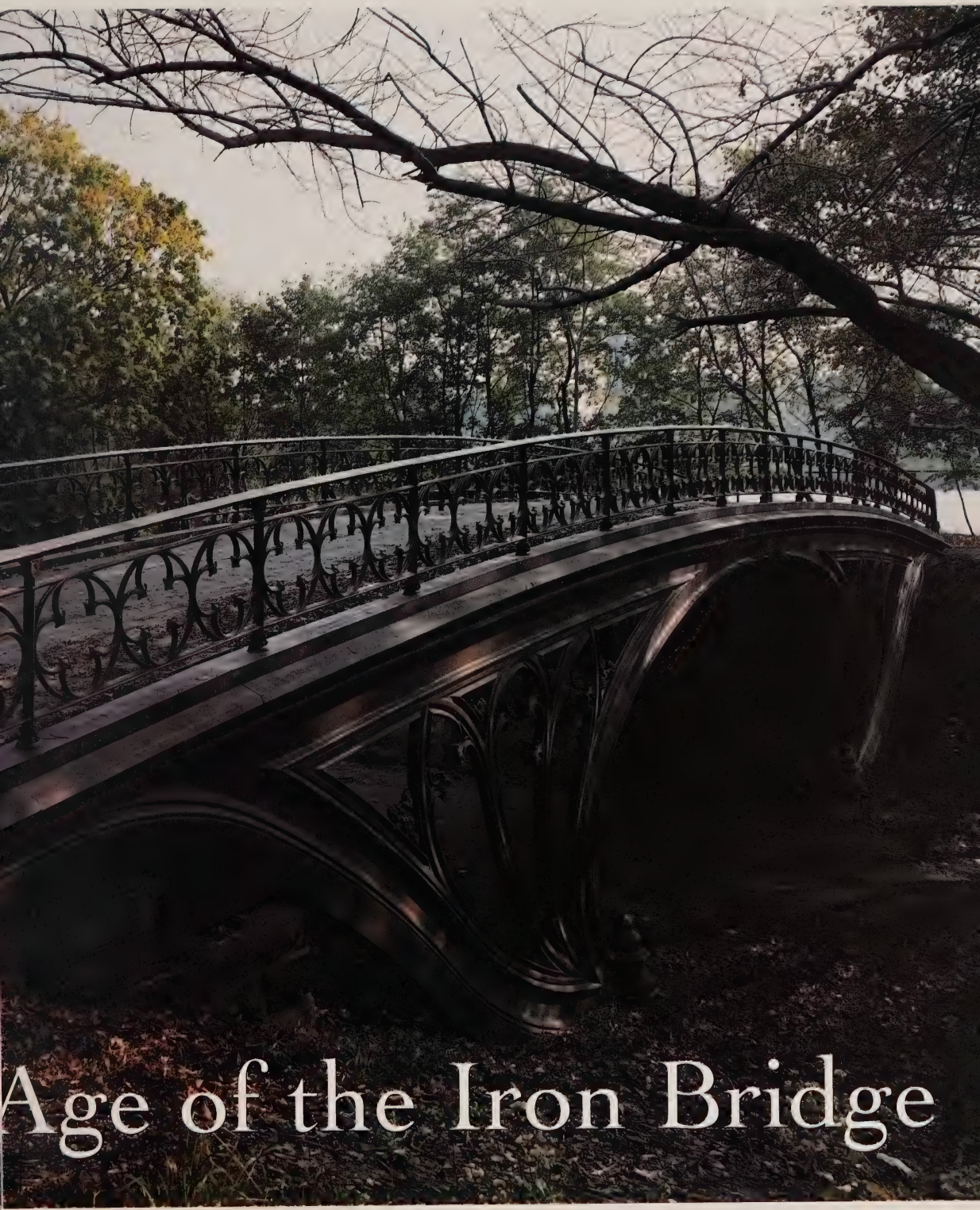
Most of the iron bridges that still sur-

They spanned the enormous gap between wood and steel in America, and although the few that survive are little appreciated today, they are the lovely remnants of an era of revolutionary technological change

BY ERIC DELONY

This ornate Gothic arch in New York City's Central Park, designed by Calvert Vaux and Jacob Wrey Mould and built in 1864, bears the prosaic name of Bridge 28.

JET LOWE, HISTORIC AMERICAN ENGINEERING RECORD, NATIONAL PARK SERVICE



Age of the Iron Bridge

THE IRON truss is the rarest and least recognized American bridge type, yet in some ways the most technologically significant.

vive are in the eastern United States, chiefly in New York, Pennsylvania, and Ohio, with a few in New England and a few more in the Midwest and mountain states. Of all the basic American bridge types—including rustic covered wooden, stalwart stone or concrete arch, foursquare steel girder, and graceful suspension—the rarest and least appreciated is the cast- and wrought-iron truss. Yet in some ways it is the most technologically significant. Every molding, pin, nut, and bolt, the way the diagonals, verticals, top chords, and eyebars are fastened together, all help these gravity-defying structures resist the forces of nature and mankind.

You can feel a truss bridge work by holding its members as an automobile crosses. The deck gives way under the weight of the load but regains its original level once the car has passed. The wrought-iron diagonals stretch, and the upper chord deflects slightly; then they too return to their original configurations. The bridge is an organism, and it functions as it does because of the elastic properties of its materials, the quality of its workmanship, and the way its parts are assembled. When you consider how many times one of these bridges has been asked to flex over a hundred years, you can begin to understand its remarkable qualities.

Unfortunately America's iron bridges have been almost universally disregarded and forgotten, even by preservationists and engineers. They exemplify fundamental American values of craft, entrepreneurialism, and creativity. They helped Americans cross thousands of streams and rivers, reach new markets, and create new businesses as the frontier moved west. Hundreds of patents on iron trusses were granted for them; while many went to trained engineers, others were awarded to crafters, millwrights, and mechanics. These unschooled "apple-tree engineers" recognized a need and sought engineering solutions that proved to be practical, if sometimes bizarre. If they are not saved now, these irreplaceable artifacts of the American landscape, both rural and urban, are threatened with extinction.

A truss is simply an interconnected framework of beams that holds something up. The beams are usually arranged in a repeated triangular pattern, since a triangle cannot be distorted by stress. In a truss bridge two long, usually straight members, known as chords, form the top and bottom; they are connected by a web of vertical posts and diagonals. The bridge is supported at the ends by abutments and sometimes in the middle by piers. A properly designed and built truss will distribute stresses throughout its structure, allowing the bridge to safely support its own weight, the weight of vehicles crossing it, and wind loads. The truss does not support the roadway from above, like a suspension bridge, or from below, like an arch bridge; rather, it makes the roadway stiffer and stronger, helping it hold together against the various loads it encounters.

Ancient Roman rules of truss design were revived during the sixteenth century by Andrea Palladio, the Italian architect. After Palladio the concept was largely forgotten for nearly two hundred years until two Swiss carpenters, the Grubenmann brothers, Johann and Hans, built several covered wooden truss bridges. But although Europeans pioneered the truss bridge, America's wide-open spaces and rugged terrain made it inevitable that the technique would see its greatest development here.

The growing, mobile population in America in the early nineteenth century needed transportation networks—first canals and turnpikes, then railroads—to settle and serve the vast, uncharted land. No country in the world needed good, permanent bridges more. The young nation was coursed by hundreds of rivers, thousands of creeks, and millions of acres of swamps. Physical unification was impossible until engineers and builders overcame the inconvenient intervention of water.

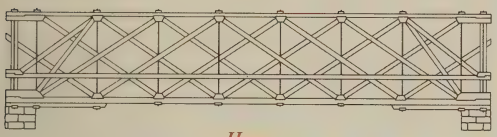
America's truss lineage begins in the early nineteenth century with the Burr, Town, Long, and Howe trusses, which were made primarily of wood, or wood with some iron parts. It continues with the Pratt and Warren trusses, which were designed and first built in wood but later adapted for iron. This evolutionary process was essentially empirical, with the sizes of members determined from the results of previous failures or from study models. Then in 1841, toward the end of the empirical period, Squire Whipple, the father of iron bridge building in America, introduced his bowstring arch. It was the first successful all-metal truss bridge, and its design was guided by scientific principles.

One way to trace the development of bridge design is to look at patents. The first patented bridge system widely used in the United States was introduced by Theodore Burr in 1806. The Burr arch-truss combined an arch and a parallel-chord truss, with the two elements working together: the arch carried the load, and the truss served as a stiffener. This system was used extensively on highways and railroads until mid-century. The next major step was Ithiel Town's lattice truss, patented in 1820, which had a number of advantages for use in the wilderness. It could be built of plank, usually three or four inches thick; intricate joints were not required; all connections could be made of round oak pins; the chord and web members were all formed from timbers of the same size, four-by-tens, which were readily available in convenient lengths; and the piers and abutments could be light because they were freed from horizontal pressures, which would have come from using an arch.

Town's design was the first straight truss bridge, with no arch, and its ease of erection made it a cheap and popular

Some Popular Truss Types

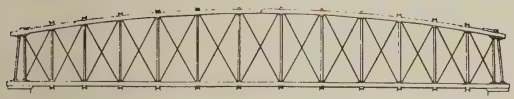
Town



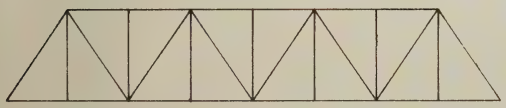
Howe

Whipple bowstring

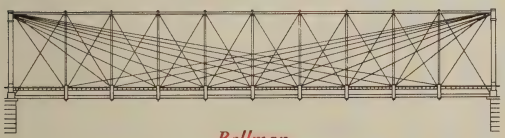
Whipple trapezoidal



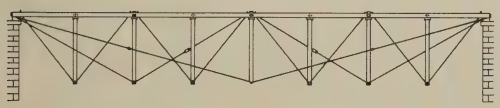
Pratt



Warren



Bollman



Fink deck

choice for canal aqueducts, turnpikes, and railroad bridges. Town accumulated quite a fortune by collecting royalties of a dollar a foot on bridges using his design. As early as 1831 he suggested that his truss might be made from iron, but no builder tried it until 1859.

After Town, the next successful patents (there were many unsuccessful ones) for trussing systems were granted to Col. Stephen Harriman Long. Long was an Army topographical engineer working for the Baltimore & Ohio Railroad who received four patents between 1830 and 1839. Like Whipple after him, Long based his trusses on scientific principles, and they were notable for their simplicity and ease of assembly.

The first important move away from wooden construction came in 1840, when William Howe (an uncle of Elias Howe of sewing-machine fame) patented the Howe truss. In profile it looked very much like the Long truss, but Howe specified vertical wrought-iron tension rods as well as heavy wooden diagonal compression members. This foreshadowed another combination of two materials—cast and wrought iron—ten years down the road. The Howe truss may be the closest that wooden-bridge design ever came to perfection. For simplicity of construction, rapidity of erection, and ease of replacing parts, it stands without rival.

In 1841 Squire Whipple patented the iron bowstring arch, and six years later he used it to illustrate America's first text (and possibly the world's first) on scientific truss-bridge design. Whipple's major breakthrough was analyzing truss members as a system of forces in equilibrium. Thomas Pratt, an engineer, and his father, Caleb, an architect, developed and patented a truss in 1844 that was the reverse of Howe's, with vertical wooden compression members and diagonal iron tension rods. The Pratt truss did not enjoy the popularity of the Howe at first because it was less rigid and more expensive, since it used more iron. As the cost of iron decreased, however, the price difference decreased as well, making the Pratt more attractive because of its simpler connections and more logical distribution of stresses.

The final important truss configuration was the Warren, or triangular, truss. It was an improvement on a design patented in France in 1838 by a Belgian engineer named Neuville. Though these were the primary patents, many surviving bridges have ingenious and diverse designs that weren't patented. They show peculiarities of having grown out of wooden-bridge design, idiosyncrasies that were discarded one by one for reasons of complexity, inadaptability, and the emergence of better solutions. The trusses that survived the wood-to-iron transition and endured into the twentieth century—the Pratt and the Warren—were simple skeletal forms that adapted well to iron and eventually to steel.

Bridge engineering evolved differently here from the way it did in Europe. In Britain the crown represented private enterprise, and Parliament had to approve all public works, while in France financing and design emanated centrally from Paris. In America engineering came to be dominated by entrepreneurs

YOU CAN feel a truss bridge work: the upper chord deflects, the wrought-iron diagonals stretch, the deck gives slightly.

and craftsmen, largely self-taught at first and interested in doing rather than studying.

The first decades of the nineteenth century were the era of the carpenter engineer. Timothy Palmer and Theodore Burr (both carpenters), Lewis Wernwag (a mechanic), and Ithiel Town (an architect) continued the wooden-truss methods of Palladio and the Grubenmann brothers with forms based on intuition, pragmatic rules of thumb, and knowledge passed from master to apprentice. Their objectives were simplicity, easy construction, and improved details, particularly the connections where parts came together. Large eastern rivers like the Connecticut, the Hudson, the Delaware, and the Potomac were bridged with wooden trusses of unprecedented length that astounded visiting European engineers.

As the country expanded, the need to cross vast distances interrupted by high mountains and wide rivers combined with a general shortage of capital to ordain the construction of cheap, rapidly built, temporary bridges. Settlers hoped to make their roads and spans more permanent later. European countries, smaller, richer, and long settled, were meanwhile building monumental structures for the ages.

Fink's first major bridge, over the Monongahela at Fairmont, West Virginia, built in 1852.

The first engineering students in America were instructed at the U.S. Military Academy—West Point—which was established in 1802. Under the direction of Sylvanus Thayer, appointed superintendent in 1817, engineering education at the academy was modeled after that at France's Ecole Polytechnique, which had been founded in 1794. Before starting the job, Thayer visited Europe to study military schools, armies, and fortifications, and his choice for professor of civil engineering was Claudius Crozet, a graduate of the Ecole Polytechnique. Academy-trained engineers knew theory and applied it, but there were not enough of them to address the needs of a fast-developing country. Consequently the craftsman-millwright-founder, who learned his skills by apprenticeship, built at least as many bridges as the educated engineer in the early part of the century. And he had to be energetic, self-reliant, and ingenious, a jack-of-all-trades who could solve each problem anew with limited resources, little time, and few precedents. Bridging small streams was part of the pioneer's life.

The world's first iron bridge was cast in 1778 at England's Coalbrookdale Ironworks and erected the following year over the River Severn, to demonstrate the versatility of cast iron. Designed by an architect, Thomas Farnolls Pritchard, it spanned one hundred feet on five cast-iron ribs. Today, as when it was built, it is the centerpiece of Ironbridge Gorge, one of the world's great open-air museums and the destination of bridge aficionados worldwide.

The great pamphleteer of the American Revolution, Thomas Paine, was probably familiar with that bridge, and he made himself a champion of iron bridges as well as of liberty. Paine realized that stone and wood, though excellent in compression, were poor in tension—or in the case of wood, hard to splice in a good tension connection. In 1786 he designed a four-hundred-foot cast- and wrought-iron arch bridge with thirteenarched ribs—one for each state in the new union.

Today some skeptical European historians doubt that a radical political philosopher untrained in the building arts could possibly have conceived such a workable plan and suggest that he may have stolen the idea from a model he saw in Paris in 1781. Whatever its origin, Paine's design, after being favorably reviewed by the French Academy of Sciences, was awarded a British patent in 1788. With the help of Walker Brothers, a family of iron founders in Rotherham, England, he built a prototype and displayed it for several weeks in front of the Stingo Pub in Paddington, near London.

Paine's campaign for iron bridges ultimately came to naught, at least as far as America was concerned, and the material was not seriously considered in the United States until the 1830s, when Town and Long suggested that their

SMITHSONIAN INSTITUTION

wooden-bridge patents could be constructed in iron. In 1833 August Canfield, a West Point graduate working in Paterson, New Jersey, patented America's first bridge designed specifically to be made from iron, but it was not practical and was never built. This country's first all-iron bridge was the Dunlap Creek Bridge, completed in 1839, which still stands (see box on page 17). Erected on the Cumberland Road in Brownsville, Pennsylvania, it was an evolutionary anomaly. Instead of a truss, Richard Delafield built a heavier, more expensive cast-iron arch bridge. Presumably his West Point education made him aware of the favored style of construction in Britain and France. Though he claimed his idea was original, the concept is similar to the Pont du Carrousel over the Seine in Paris, built in 1834.

After Dunlap Creek inaugurated the use of iron, two bridges spanning New York State's Erie Canal marked its earliest use in truss bridges. In 1840 Earl Trumbull built the first iron truss bridge in America, a span of seventy-seven feet at Frankfort, New York. Months later at Utica, Squire Whipple built his famous bowstring arch (so called because the shape of the top chord and the deck resembled a bow used in archery). Whipple was born in 1804 to a farmer in Hardwick, Massachusetts, and studied engineering at Union College, graduating in 1830. After first working as a rodman and leveler on the Baltimore & Ohio Railroad, he became a surveyor on the Erie Canal, and when engineering work was not available, he invented and manufactured engineering and surveying instruments. In 1841 he patented his bowstring arch truss; he later started one of the country's earliest bridge companies and built hundreds of iron bridges for canal, rail, and highway use.

A Fink-designed 1850s Baltimore & Ohio Railroad bridge near Clarksburg, West Virginia.

In 1846 Whipple published a pamphlet called *An Essay on Bridge Building*, which the next year he expanded to book length—America's, if not the world's, first book on mathematical truss analysis. The volume was ignored for years, but it marked the beginning of rational bridge design in America, which would eventually raise the discipline from a craft to a profession.

During the 1840s iron bridge building in America made impressive strides. In 1845 Richard Osborne, a London-born Irish-emigrant engineer working for the Philadelphia & Reading Railroad, built the country's first all-iron railroad bridge. It was known as the Manayunk Bridge, after the Philadelphia neighborhood in which it was built, and consisted of three lines of Howe trussing reaching thirty-four feet across a small stream. A single line of that trussing was donated to the Smithsonian Institution in 1911; today it serves as part of the exhibit of the *John Bull*, an early steam locomotive.

A period of rapid experimentation with the new material ensued. In 1847 Frederick Harbach built an iron Howe truss on the Western Railroad (later the Boston & Albany) near Pittsfield, Massachusetts. That same year James Milholland built a bridge for the Baltimore & Susquehanna Railroad at Bolton Station, Maryland, using girders—the first to do so in America and a design far advanced for its time. Iron girders would become a common feature of railroad bridges twenty years later.

These early designs were officially embraced by Benjamin Henry Latrobe, Jr., chief engineer of the Baltimore & Ohio. His line became the first railroad to adopt iron as standard for its bridges and moved into the forefront of advances in building bigger, stronger, longer bridges. Two engineers working with Latrobe, Wendel Bollman and Albert Fink, developed all-metal trusses of cast and wrought iron that could support more than one ton per lineal foot.

Bollman, a Baltimore pharmacist who switched to railroad work, ultimately became foreman of bridges and then master of the road for the B&O, responsible for all structures along the right-of-way. In 1858 he returned to private business, and he founded his own bridge company after the Civil War.

Albert Fink immigrated to the United States a year after graduating from the Polytechnic School in Darmstadt, Germany, in 1848. After Bollman refused him a job as a draftsman on the B&O, Latrobe hired him. Fink eventually designed and patented a truss of his own and became Latrobe's principal assistant for part of the road. He went on to be vice president and general superintendent of the Louisville & Nashville Railroad.

Bollman's first major span, erected in 1851 over the Po-

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"Not all passengers

But they all

General Motors is developing the first "pregnant" crash dummy to study the effects of collisions on expectant mothers and their babies. "This could lead to new safety features designed just for pregnant women," says Dr. David Viano, principal researcher at General Motors. "And whatever we learn, we'll share with other automakers." Dr. Viano

Can be seen.

Need protection."

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urges women to wear safety belts during pregnancy—years of research show the benefits far outweigh the risks. Position the lap belt under the bulge of the stomach and over the hip bones. Position the shoulder belt between the breasts and to the side of the bulge. At General Motors, safety isn't one thing. It's everything.

tomac at Harpers Ferry, was 124 feet long. A year later Fink put up three trusses of 205 feet each, 43 feet above the Monongahela River near Fairmont, (West) Virginia. Both Fink's and Bollman's bridges were suspension trusses, with chords and posts of cast iron and diagonal tension members of wrought iron. The tension bars had eyes at their ends that were pierced by finely turned forged pins, instead of being held in place with cast-iron trunnion blocks. This freedom of rotation meant that the trussing system could be analyzed using simple mathematical formulas. Use of the Bollman and Fink all-iron pin-connected trusses by the B&O revolutionized railroad-bridge design. Soon after, the Pennsylvania Railroad began building iron Pratt trusses stiffened with cast-iron arches, a design that served as that railroad's standard from 1851 to 1861.

After mid-century, trained engineers like Whipple, Osborne, and Fink assumed significantly greater roles in bridge design. The Whipple truss, with end posts inclined instead of straight up and diagonal tension members crossing two panels instead of one, was the first of a whole new generation of metal trusses. In 1853 Squire Whipple built a 146-foot span of this configuration for the Rensselaer & Saratoga Railroad near Troy, New York. He called it Whipple's Trapezoidal Truss. In 1859 John W. Murphy built a 163-foot span over the Morris Canal at Phillipsburg, New Jersey, for the Lehigh Valley Railroad, that was patterned on the Whipple configuration but pin-connected throughout. It became known, to Squire Whipple's chagrin, as the Murphy-Whipple, and it became the standard truss type for long-span bridges for the rest of the century.

These trusses were adequate for Eastern terrain, but as railroads expanded westward, they encountered a formidable barrier: the Ohio River. It had been bridged, of course, but as trains got heavier, much sturdier bridges were needed. Spanning the Ohio now demanded major improvements in scientific design and a deeper understanding of the way materials such as cast and wrought iron behaved under stress. Engineers developed more realistic mathematical models in which the weight of a train was concentrated at the engine and the axles, instead of being spread uniformly along the length of the bridge.

Wheel-load analysis was first proposed in 1862 by Charles Hinton, a bridge engineer for the New York Central Railroad, and it quickly became standard American railroad practice. In addition, the Pennsylvania Railroad introduced testing machines to help engineers understand and measure material behavior. In 1863 William Sellers, a Philadelphia machine builder, developed a machine with five hundred tons of capacity, capable of testing full-size structural members. This enabled Jacob H. Linville, chief engineer of the Keystone Bridge Company, to design and build truss spans so long they could bound the Ohio River.

Amasa Stone's railroad bridge at Ashtabula, Ohio, before and after its 1876 collapse. The failure led to cast iron's demise as a bridge material.

The railroads had reached the Ohio on the eve of the Civil War; crossing it, however, still required a trip on a ferryboat. Then wartime demands pushed the technology of metal truss-bridge construction to near-perfection. By the end of the war, railroads were the most powerful economic and political force in the United States. They were ready to address the broad and meandering Ohio and Mississippi—an extensive, wide, fast-moving, and deep river system that separated the Eastern United States from the West and the North from the South.

To cross these rivers, engineers developed new, ever-longer-span trusses. The Steubenville Bridge, in Ohio, with

BOTH: ASHTABULA COUNTY HISTORICAL SOCIETY, JEFFERSON, OHIO

First and Still There

BY FRANCES C. ROBB

The sturdy landmark bridge in its utilitarian setting, 1920s.

It isn't exactly glamorous, but at age 155, America's oldest iron bridge is as good as new

Sixty years after the world's first cast-iron bridge was built in England, Capt. Richard Delafield of the U.S. Army Corps of Engineers erected America's first cast-iron bridge, on the Cumberland Road. The 130-mile portion of the road from Cumberland, Maryland, to Wheeling, (West) Virginia, which opened in 1818, had been built by the federal government as a land route between the Ohio River and the Eastern states. However, as the result of niggardly allocations for maintenance, the road had quickly fallen into disrepair.

In 1832 the three states traversed by the road—Maryland, Pennsylvania, and Virginia—agreed to assume responsibility for its upkeep if the Corps of Engineers would restore it first. Most of the resulting work was strictly repair, but Delafield was responsible for building two new bridges, including one at Brownsville, in southwestern Pennsylvania, across Dunlap Creek. An early chain-suspension bridge at Brownsville had collapsed under a snow load in 1820. By 1832 an Army engineer predicted that its latest replacement "would not stand a twelvemonth."

When the time came to build a permanent replacement, complications arose instantly. Delafield, unsatisfied with the locally available stone and concerned over the inflammability of wood, decided to make the bridge from cast iron. The several issues that had to be resolved before construction could begin—among them the selection of the exact site—were decided only after local politicking fervent enough to eventually involve even President Andrew Jackson. The Corps of Engineers briefly considered abandoning the bridge project in 1834 due to cost constraints. Delafield was unhappy with the final location, believing that it afforded "an indifferent approach"; his 1835 annual report groused that "local interests coming in collision with the public good, arrested the progress of this work."

These matters took more than two years to resolve, after which new contracts had to be negotiated because of large increases in prevailing wages and the cost of materials (especially iron, which rose from thirty-five to fifty-five dollars per ton). To cast the iron, Delafield rented the nearby foundry of John Snowden and paid its workers directly from federal funds. Work finally began in the summer of 1835.

The bridge Delafield designed for Dunlap Creek had a span of 80 feet with an 8-foot rise, and it contained 167 tons of iron, cast into 250 pieces. The semicircular arch consisted of five parallel tubular ribs, each made from nine identical 14-foot segments flanged at the ends and bolted together. The deck was made of cast-iron plates covered with crushed gravel. Delafield considered his bridge to be different "in its principles of construction from any of which I could find of either English or French engineers."

Delafield had planned to build it in a year, but construction was beset with problems from the beginning. Heavy rains, high water, and labor shortages delayed progress, and by September 1836 contractors had completed only one stone abutment. Meanwhile, at the foundry, casting had begun, but the second year of construction ended with several large pieces still not cast. Delafield expected the remaining work to take another two months, but despite his confidence, the bridge was not completely finished until 1839, long after all other improvements on the road had been finished (though it began to carry traffic as early as July 1838). After placement of the roadway plates and iron rail, and three coats of white lead paint, the bridge was officially opened on July 4. By this time Delafield had been reassigned as superintendent of the U.S. Military Academy.

It ended up costing almost $40,000, although Delafield's 1833 estimate had been $21,000. This made it exorbitantly expensive; a comparably sized stone bridge would have cost about $23,000, and a wooden one $7,000. Only the federal government could afford to pay so much. It's no surprise, then, that Delafield's design, despite its evident sturdiness, was not widely copied, and America's next iron arch bridge was not built until 1858.

Over the years, few alterations have been made to the nineteenth-century structure. In the 1920s the state added sidewalks supported by cantilevers, but no other major changes have been necessary to keep Delafield's hard-won bridge in service. Today, after more than a century and a half, it continues to carry traffic across Dunlap Creek. It is so inconspicuous that many motorists do not even realize they have crossed a bridge at all—let alone the oldest iron bridge in the country.

Frances C. Robb is an independent scholar in Pittsburgh, Pennsylvania.

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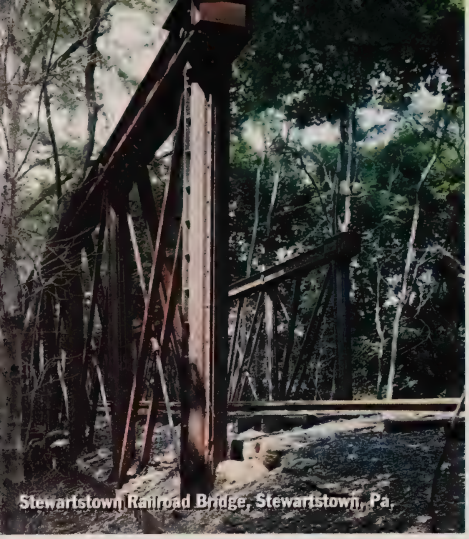
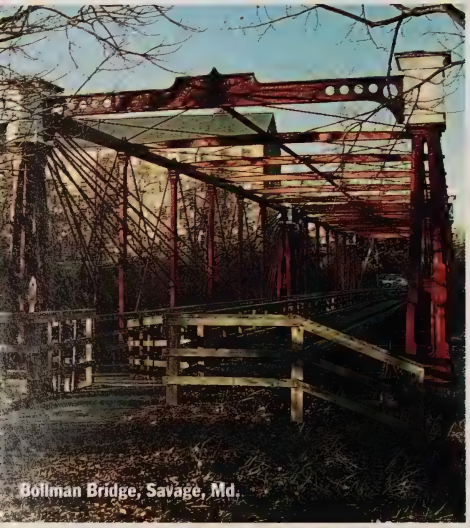


Stewartstown Railroad Bridge, Stewartstown, Pa.

Henszey's Wrought-Iron Arch Bridge, Wanamakers, Pa.

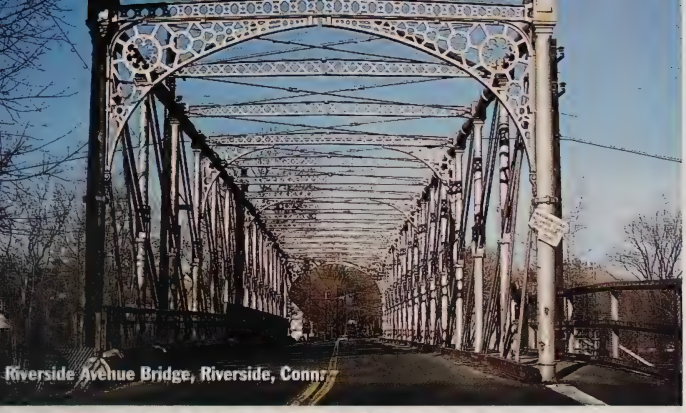


Bollman Bridge, Savage, Md.

Falling Rock Camp Bridge, Newark vicinity, Ohio

Zoarville Station Bridge, Zoarville, Ohio

Scarlets Mill Bridge, Scarlets Mill, Pa.



Riverside Avenue Bridge, Riverside, Conn.

Roderick Bridge, near Coshocton, Ohio

a channel span of 320 feet and trusses 28 feet deep, was the first. Linville designed it for the Pittsburgh, Cincinnati, Chicago & St. Louis Railroad, using Whipple's Trapezoidal Truss as his pattern. Its completion in 1864 began the era of long-span truss-bridge design in America. Albert Fink followed with a hybrid Whipple-Pratt bridge over the same river at Louisville in 1870, with main spans of 360 and 390 feet. The Whipple and Fink types both grew popular because they could cover long distances but had short panel lengths for even load distributions. The longest Fink-truss span ever built was only 306 feet, but the Murphy-Whipple, with its greater rigidity, reached an unprecedented 518 feet.

The most enduring achievement of the postwar period, however, was the bridging of the mighty Mississippi below its confluence with the Missouri. This astounding feat was accomplished in 1874 by James Buchanan Eads, another nineteenth-century Renaissance man who, like Paine and Bollman, was not a trained engineer. (See "Eads and the Navy of the Mississippi," *Invention & Technology*, Spring 1994.) The Eads Bridge, the oldest and most graceful of the Mississippi River bridges, shattered all engineering precedents with its double-deck design and its three ribbed steel arches that each spanned more than five hundred feet. The arches were cantilevered and supported by cables as they were being built, eliminating the need for falsework, which would have been impossible on the broad, deep, fast-flowing Mississippi. Pneumatic caissons (submerged, floorless cylinders pumped with air), rather than coffer dams built from the surface, were another innovation. And the Eads Bridge marked the first major use of steel in bridge construction.

Bridge mix: An assortment of survivors shows the versatility of cast and wrought iron and the ingenuity and adaptability of nineteenth-century engineers.

The triumph of spanning the Mississippi in 1874 was offset in 1876 by the Ashtabula Bridge disaster. On a cold, miserable, snowy Ohio night a few days after Christmas that year, seventy-six people perished when an 1865 cast- and wrought-iron bridge collapsed, plunging a passenger train into the Ashtabula River. Many railroad bridges had collapsed before, but never with so great a loss of life. The accident shook the engineering profession and weakened the railroad industry's confidence in its bridges. The ensuing investigation and report by the American Society of Civil Engineers condemned combination cast- and wrought-iron bridges in favor

RIVERSIDE AVENUE BRIDGE—COURTNEY FISHER; FALLING ROCK CAMP BRIDGE AND RODERICK BRIDGE—W. G. KEENER AND CHRISTOPHER S. DUCKWORTH; BOLLMAN BRIDGE—ERIC DeLONY; ALL OTHERS: JOSEPH ELLIOTT, HISTORIC AMERICAN ENGINEERING RECORD

BRIDGES WERE the most highly developed kind of structure, and consulting bridge engineers were the most respected practitioners.

of all-wrought-iron construction, riveted rather than pin-connected.

Three years later, in December 1879, the British railroad industry suffered a similar catastrophe when a combination bridge failed under a passing train. Thirteen spans of the two-mile-long viaduct across the Firth of Tay at Dundee, Scotland, collapsed, giving British engineers renewed respect for the forces of nature. A court of inquiry determined that the failure had been caused by ignorance of metallurgy, uneven manufacturing techniques, defective castings, and instability under wind loads.

In the wake of these collapses, bridges were examined in both countries, and many instances of defective design and construction turned up. Floor systems were too frail for the new, heavier engines. Broken castings illustrated the unreliability of cast iron even when used just for joint blocks (the pieces used to join one member to another). Connection fittings as well as the cross-sectional areas of members—the details upon which the capacity of a bridge depends—were found inadequate. Clearly, bridge design had a long way to go.

The number of bridge-fabricating companies had been exploding during the second half of the nineteenth century, nearly doubling every decade. In 1850 only 15 such companies were operating in the United States; on April 13, 1900,

THE OLDEST SURVIVORS

Seventy-one iron bridges from the golden age still stand. They are mostly combination bridges, made of both cast and wrought iron. Here are all seventy-one arranged geographically and listed with their designers and, where indicated, builders. (NOTE: Several of the bridges listed are privately owned. Owner's consent should be secured before venturing onto private property.)

New England

1. Upper Pacific Mills Bridge (1864). North Canal, Lawrence, Mass. Thomas Moseley. Moseley Iron Building Works, Boston, builder.
2. Atherton Bridge (1870). Bolton Road over Nashua River, Lancaster, Mass. Simeon S. Post. J. H. Cofrode & Company, Philadelphia, builder.
3. Elm Street Bridge (1870). Elm Street over Ottauquechee River, Woodstock, Vt. Charles H. Parker. National Bridge & Iron Works, Boston, builder.
4. (Lower) Rollstone Street Bridge (1870). Fitchburg, Mass. Charles H. Parker. National Bridge & Iron Works, Boston, builder.
5. Vine Street Bridge (c. 1870). Vine Street over Central Vermont Railroad, Northfield, Vt. Charles H. Parker. National Bridge & Iron Works, Boston, builder.
6. North Village Bridge (1871). North Main Street over French (Stoney) River, Webster, Mass. Charles H. Parker. National Bridge & Iron Works, Boston, builder.
7. Ponakin Bridge (1871). Ponakin Road over North Nashua River, Lancaster, Mass. Simeon S. Post. Watson Manufacturing Co., Paterson, N.J., builder.
8. Riverside Avenue Bridge (1871). Riverside Avenue over Amtrak Northeast Corridor, Riverside, Conn. Francis C. Lowthorp. Keystone Bridge Co., Pittsburgh, Pa., builder.
9. Pine Creek Park (Mine Hill Road) Bridge (1872). Old Dam Road, Fairfield, Conn. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, Pa., builder.
10. Tilton Island Park Bridge (1881). Pedestrian access to Tilton Island Park over Winnipesaukee River, Tilton, N.H. Lucius Truesdell. A. D. Briggs & Company, Springfield, Mass., builder.

New York

1. Whipple Cast- & Wrought-Iron Bowstring Truss Bridge (1851). Chili Mills. Squire Whipple.
2. Change (Aldrich's Crossover) Bridge (1858). Palmyra.
3. Whipple Cast- & Wrought-Iron Pony Pratt Truss Bridge (c. 1860). Private-access bridge over Gulf Stream to private residence adjacent to N.Y. Route 51, south of Ilion.
4–8. Central Park bridges, New York City: (a) Pine Bank Arch (1861), (b) Bow Bridge (1862), (c) Gothic Arch (1864), (d) Reservoir Bridge Southwest (1864), (e) Reservoir Bridge Southeast (1865). All: Calvert Vaux and J. Wrey Mould.
9. Whipple Cast & Wrought-Iron Bowstring Truss Bridge (1867). Private road over unnamed stream that leads into the Normans Kill farm, Albany. Squire Whipple. Simon DeGraff, builder.
10. Cayadutta Creek Bridge (c. 1869). Moved in 1979 from Johnstown to Union College campus, Schenectady. Squire Whipple. Shipman & Son, Springfield Center, builder.
11. Second Cayadutta Bridge (c. 1869). Spanning Cayadutta Creek, Fonda. Squire Whipple, builder.
12. Shaw Bridge (1870). Van Wyck Lane (formerly Old Albany Post Road), over Claverack Creek, near N.Y. Route 9H, Claverack. Squire Whipple. J. D. Hutchinson, builder.
13. Parker Truss Bridge (c. 1870). St. Lawrence County. Charles H. Parker. National Bridge & Iron Works, Boston, builder.
14. Talcottville Bridge (c. 1870). Talcottville. Squire Whipple.
15. Watkins Glen Bridge (c. 1870). Park footpath over gorge, Watkins Glen State Park. John L. Foreman, builder.
16. Tioronda Bridge (1873). South Avenue over Fishkill Creek, Beacon. Glass, Schneider & Rezner, builder.
17. Upper Keeseville Bridge (1878). River Street over Ausable River, Keeseville. S. W. Murray. Murray, Dougal & Co., Milton, Pa., builder.

Pennsylvania

1. Dunlap Creek Bridge (1839). Old U.S. Route 40 over Dunlap Creek, Brownsville. Richard Delafield, engineer. John Snowden and John Herbertson, foundrymen.
2. Halls-Station Bridge (Philadelphia & Reading Railroad) (c. 1846). Private road over Conrail tracks, Muncy. Richard B. Osborne.
3. Main Street Bridge (1851, 1874). Formerly Main Street over French Creek, Phoenixville; moved to Chester County Park.
4–6. Haupt truss bridges (Pennsylvania Railroad) (all c. 1854): (a) Railroaders' Memorial Museum, Altoona, (b) Spring Mill Road over the Main Line, Villanova, (c) Church Road over the Main Line, Ardmore. All: Herman Haupt. Altoona shops, Pennsylvania Railroad, builder.
7. Walnut Street Bridge (c. 1860). Formerly spanning Saucon Creek, Hellertown; removed to a nearby field. Charles N. Beckel. Beckel Iron Foundry & Machine Shop, builder.
8. Hares Hill Road Bridge (1869). Hares Hill Road over French Creek, Kimberton. Thomas Moseley. Moseley Iron Bridge & Roof Co., Philadelphia, builder.
9. Henszey's Wrought-Iron Arch Bridge (1869). Kings Road over Ontelaunee Creek, Wana-

there were more than 190, and on that day J. P. Morgan consolidated 24 of them into the American Bridge Company.

One firm not absorbed by Morgan was the Phoenix Bridge Company, located about an hour out of Philadelphia on the Reading Railroad. It was a bustling enterprise established in 1790 where you could follow the building of a bridge from iron ore to finished product. At the machine shop wrought iron came from the puddling furnace to be rolled, planed, drilled, and riveted into the Phoenix column, a proprietary section patented by one of the owners, Samuel J. Reeves, in 1862. Everything was made on the most modern machines, allowing great accuracy and precise duplication of parts.

Samuel Reeves also developed the Phoenix bridge (yet another Murphy-Whipple configuration), which contributed to the demise of the composite cast- and wrought-iron structure. It used the Phoenix column, made entirely of wrought iron, and was so lightweight and strong that it rendered the price advantage of cast iron immaterial.

Before shipping a bridge to the spot where it would be erected, mechanics at Phoenix assembled the parts on the shop floor to ensure proper length and fit. They were marked so that workmen in the field could quickly reassemble them. Field erection required scaffolding—a falsework of wood capable of supporting the weight of the bridge until it was finished. If the site was a deep gorge, the falsework was often as elaborate and expensive as the finished bridge. The technique of prefabricating and preassembling all the parts to guarantee an exact fit and then securing the members with pins became known as the "American plan."

Here, as in other aspects of bridge design and construc-

makers. Joseph G. Henszey. Continental Bridge Company, Philadelphia, builder.
10. Rush's Mill Bridge (1869). Union Canal bicycle and walking trail over Plum Creek near Blue Marsh Lake, Reading vicinity. Simon Dreibelbies, builder.
11. Old Mill Road Bridge (1870). Old Mill Road over Saucon Creek, Hellertown. Charles N. Beckel. Beckel Iron Foundry & Machine Shop, Bethlehem, builder.
12. City Line Road Bridge (1870). Moved to Sand Island, Bethlehem. Charles N. Beckel. Beckel Iron Foundry & Machine Shop, Bethlehem, builder.
13. Stewartstown Railroad Bridge (1870). Over Valley Road, Stewartstown. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, builder.
14. Youngsville Airport Bridge (c. 1870). Airport Road over Brokenstraw Creek, Youngsville. Squire Whipple.
15. Bollman Bridge (B&O Railroad) (1871). Township Route 516 over Pittsburgh Branch, Meyersdale. Wendel Bollman. Patapsco Bridge & Iron Works, Baltimore, Md., builder.
16. Mead Avenue Bridge (1871, rebuilt 1937). Mead Avenue over French Creek, Meadville. Penn Bridge Works, New Brighton, builder.
17. Scarlets Mill Bridge (1881). Scarlets Mill. John L. Foreman. Pottstown shops, Reading Railroad, builder.
18. Tank Farm Road Bridge (1881). Moved from Tank Farm Road over Conrail tracks, Macungie, to Hugh Moore Historical Park & Canal Museum, Easton. John L. Foreman. Pottstown shops, Reading Railroad, builder.

Middle Atlantic

1. Manayunk Bridge (Philadelphia & Reading Railroad) (1845). National Museum of American History, Smithsonian Institution, Washington, D.C. Richard B. Osborne.
2. Rock Creek Bridge (Washington Aqueduct) (1860). Pennsylvania Avenue and Washington Aqueduct over Rock Creek, Washington, D.C. Montgomery C. Meigs.
3. Musconetcong River Bridge (1868). Unidentified road over Musconetcong River, New Hampton, N.J. William and Charles Cowin. Cowin Iron Works, Lambertville, N.J., builder.
4. Bollman Truss Bridge (B&O Railroad) (c. 1869). Abandoned B&O spur over Little Patuxent River, Savage, Md. Wendel Bollman. Patapsco Bridge & Iron Works, Baltimore, Md., builder.
5. School Street Bridge (1870). School Street over Spruce Run, Glen Gardner, N.J. William and Charles Cowin. Cowin Iron Works, Lambertville, N.J., builder.
6. West Main Street Bridge (1870). West Main Street over South Branch of Raritan River, Clinton, N.J. William and Charles Cowin. Cowin Iron Works, Lambertville, N.J., builder.
7. Lombard Street Bridge (1877). Streetcar Museum, Baltimore, Md. James Curran, Baltimore Water Dept., and Wendel Bollman. Patapsco Bridge & Iron Works, Baltimore, Md., builder.

Ohio

1. Davenport Truss Bridge (1859). Oak Knoll Park, Massillon. Joseph Davenport. Russell Bridge Co., Massillon, builder.
2. Blackhoof Street (Moulton Angle Road) Bridge (1864). Over Miami and Erie Canal, Lions Club Park, New Bremen. David H. Morrison. Columbia Bridge Co., Dayton, builder.
3. Zoarville Station Bridge (1868). Abandoned Ohio Route 212, Zoarville vicinity. Charles Shaler Smith. Smith, Latrobe & Co., Baltimore, Md., builder.
4. Laymon Road Bridge (1871, 1991). Wilmington. Joseph Davenport. Massillon Bridge Co., builder.
5. County Engineer's Garage Bridge (1872). South Market Street over Beaver Creek, Lisbon. Joseph Davenport. Massillon Bridge Co., builder.
6. Roderick Bridge (1872). Coshocton vicinity. Squire Whipple and James W. Shipman. Coshocton Iron Works, builder.
7. Falling Rock Camp Bridge (c. 1872). Newark vicinity; similar to bridge built by the Cleveland Bridge & Car Works, NcNairy. Claflen & Company, proprietors.
8. Towpath footbridge (c. 1872). Over Ohio and Erie Canal at Uppermost Triple Lock, Roscoe Village, Coshocton.
9. Sockman Road Bridge (1873). Fredericktown vicinity. Joseph Davenport. Russell Bridge Co., Massillon, builder.
10. Howard Bridge (1874). Abandoned County Route 35 over Kokosing River, Howard. David H. and Charles C. Morrison. Columbia Bridge Co., Dayton, builder.
11. Egypt Pike Bridge (1877). New Holland. Jonathan and Zimri Wall. Champion Iron Bridge Co., Wilmington, builder.

Midwest

1. Cloie Branch Bridge (1868). Moved from road over Cloie Branch to bicycle path, Dubuque County, Iowa. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, Pa., builder.
2. White Water Creek Bridge (1868). Unidentified road over White Water Creek, Dubuque County, Iowa. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, Pa., builder.
3. Eureka Wrought-Iron Bowstring Arch-Rod Bridge (1874). Formerly in Frankville, Iowa; moved to city park, Castalia, Iowa. William H. Allen and Oliver H. Perry. Allen, McEvoy & Co., Beloit, Wis., builder.
4. Burton Lane Bridge (c. 1875). Old Burton Lane (County Route 189) over Indian Creek, Martinsville, Ind. Joseph Davenport. Massillon Bridge Co., Massillon, Ohio, builder.
5. Paint Creek Bridge (c. 1875). County Route 25 over Paint Creek, near Camden, Ind. Joseph Davenport. Massillon Bridge Co., Massillon, Ohio, builder.
6. Hardin City Bridge (1879). Displayed alongside county road, Eldora vicinity, Iowa. Western Bridge Works, Fort Wayne, Ind., builder.

South and West

1. Fairground Street Bridge (c. 1870). Fairground Street over Illinois Central Railroad, Vicksburg, Miss. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, Pa., builder.
2. Kassler Bridge (c. 1870). Moved from Kassler, Colo., to unidentified road over South Platte River, Bailey, Colo. Jacob H. Linville. Keystone Bridge Co., Pittsburgh, Pa., builder.

AFTER 1876 railroads started holding competitions instead of relying on off-the-shelf designs or building bridges in-house.

tion, American and European practices diverged. In Europe, where bridges were riveted together, erection time was longer and the costs were consequently higher. A riveted Town lattice truss of 160-foot span took ten to twelve days to build; a Phoenix truss of similar span could actually go up in eight or nine hours. Eventually American engineers would opt for slower, costlier all-riveted construction, but the American plan prevailed in this country until the end of the century.

Partly because of this, American bridge manufacturers had the lowest prices and did the fastest work in the world and competed successfully in world markets. Despite the Ashtabula disaster, American bridge shops were by the 1870s as high tech as anything anywhere. They even employed the latest in corporate organization and structure. Morgan's American Bridge Company had a financial department and auditor, a purchasing department, an executive and secretariat, and engineering, operating, contracting, and mechanical departments—the nucleus of a modern industrial corporation.

Central Park's 1862 Bow Bridge, America's oldest wrought-iron girder bridge.

In the last quarter of the century, the ever-mounting demands of the railroads transformed American bridge engineering. Until 1876 bridge design and construction were almost exclusively controlled by companies that promoted one particular style—for instance, the National Bridge Company of Boston's Parker truss or the Watson Machine Company of Paterson, New Jersey's Post truss. After the Ashtabula disaster, railroads started holding design competitions based on specifications and performance standards instead of relying on off-the-shelf designs or in-house bridge building. A bridge over the Ohio River, made in 1876 for the Cincinnati Southern Railroad, was the first large bridge project awarded on the basis of a competition. The Keystone Bridge Company of Pittsburgh was the winner.

Written specifications were something new. The first set adopted by an American railroad was drawn up in 1871 by George Morison, an engineer for the Erie Railroad. (See "The Master Builder," *Invention & Technology*, Fall 1986.) Morison went further than just setting forth specifications; he required successful bidders to submit stress diagrams, calculations, and plans before starting work, and later he personally inspected materials and workmanship in the field. Theodore Cooper wrote up specs in 1878—improving on ones written by Reeves and Morison—that became the basic form of instructions most widely used by American railroads for the rest of the century.

With the rise of design competitions, many top engineers left railroad engineering departments to enter private practice. By 1880 bridge consultants had become the first specialists within the general field of civil engineering. Bridges were the most highly developed kind of structure type, and consulting bridge engineers the most skilled and respected practitioners. They had come a very long way indeed from the frontier craftsmen who had dominated bridge building half a century before. Theodore Cooper characterized the successful bridge engineer of 1880 as not just a mere calculator of stresses but someone with a full knowledge of the practical and theoretical elements of design, manufacturing, and erection, as well as an "instinct of design."

Today we need an equally sensitive and sophisticated specialist, capable and experienced, to preserve the outstanding bridges of the past. He or she must be familiar not only with contemporary computer modeling and structural analysis, but also with nineteenth-century building materials, and the theories, formulas, and rules of thumb used by Burr, Town, Wernwag, Whipple, Linville, Morison, and the hundreds of engineers and draftsmen who cranked out designs by the mile during the nineteenth century.

Few people willfully destroy historic bridges; we usually lose them through ignorance of their importance. To preserve the historic bridges of the United States, we need the cooperation of people in transportation and engineering; preservationists, architects, and historians working alone will only partially succeed. Bridges are engineered structures, and they require the ingenuity of engineers to survive. Above all, we need an informed public that recognizes the significance of historic bridges and insists that the best ones be saved—not only for practical reasons, but for the enrichment of posterity. ★

Eric DeLony is chief of the Historic American Engineering Record/National Park Service. He is the author of Landmark American Bridges *(Bullfinch Press, 1993).*

PATTI McCONVILLE/IMAGE BANK

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The Coney Island Baby Laboratory

INCUBATORS FOR NEWBORN INFANTS WERE DEVELOPED NOT IN A MEDICAL RESEARCH FACILITY BUT AMID BARKERS, SIDESHOWS, AND GAWKING CROWDS

BY GARY R. BROWN

"YOU MAY TALK, LADIES AND GENTLEMEN, you may cough. They will not hear you. They do not even know you are here. And now, suppose you all follow me. Just come this way, if you will, and we will meet the first of our temporary visitors." For forty years millions of revelers visiting Coney Island were drawn away from the clamor

An incubator exhibit to rival Dr. Couney's was opened at the Louisiana Purchase Exposition in 1904. An epidemic killed half the babies, discouraging further competitors.

MISSOURI HISTORICAL SOCIETY, ST. LOUIS

of roller coasters and shooting galleries to see these "temporary visitors"—tiny premature babies struggling to survive in prototypical incubators.

"The Infant Incubators" was Coney Island's oddest and, at times, most popular attraction, and its admission fees subsidized the development and application of groundbreaking medical technology. The premature infants on display were being treated with equipment and techniques far more sophisticated than those available at most hospitals; they had a survival rate unsurpassed at any medical facility in the world. The man behind this bizarre phenomenon, a pioneering pediatrician and showman who became known as the Incubator Doctor, was the first in the United States to offer infants this specialized care.

Martin Arthur Couney was born in 1870, probably in Alsace. After studying medicine in Breslau, Berlin, and Leipzig, Couney traveled to Paris in the 1890s for postgraduate work under Pierre Constant Budin, a leading pediatrician who was experimenting with new methods for treating premature infants. Until that time the medical profession had given them little hope, focusing instead on care of their mothers. As a result, premature babies rarely survived. According to Budin, however, by the 1890s medical advances had made this approach unnecessary. The modern physician, he wrote, "freed from anxiety as to the fate of the mother, can now devote his attention to the needs of the infant."

It had long been known that premature newborns, lacking the body fat of full-term infants, were unable to maintain a constant body temperature. Early efforts to treat premature newborns, both systematic and makeshift, centered on keeping them warm with ovens, heated bricks, woolen garments, or hot-water bottles. In 1853 a published medical study demonstrated that these newborns experience a rapid drop in temperature, respiration, and circulation that can often lead to death. Later research showed that full-term infants experience a similar drop, but their temperature quickly rises again. The challenge was to maintain the premature infant at a uniform temperature until its body functions stabilized.

Tarnier's apparatus consisted of a double-sided wooden box insulated with sawdust and heated with hot water. Nurses monitored the temperature and added heat when needed.

In the 1870s Etienne Stéphane Tarnier, a physician, began to study the problem of premature infants and found that maintaining a constant temperature was not enough. Survival of premature infants requires isolation, faultless hygiene, appropriate feeding, and a warm, humid atmosphere. In 1880, inspired by a device used to incubate poultry, Tarnier introduced the first infant incubators—essentially large wooden boxes with glass lids and compartments to hold hot-water bottles. Using these, Tarnier was able to reduce infant mortality by 28 percent over a period of three years.

Budin was a student of Tarnier, and he quickly improved

BETTMANN ARCHIVE

on Tarnier's design. He added a thermostat, installed glass plates to permit observation of the infant, and abandoned Tarnier's water bottles in favor of natural-gas heating. In 1893 Budin was appointed head of a special unit for premature infants at the Maternité in Paris, the first hospital to offer treatment for prematurity.

He and Couney got into the exhibition business quite casually. In an effort to obtain more hospital space by generating publicity for their work, Budin prevailed upon Couney to display six incubators at the Berlin Exposition of 1896. He persuaded an esteemed German obstetrician to provide newborns from Berlin's Charity Hospital. Hoping that the admission fees would cover his expenses, Couney opened the *Kinderbrutanstalt* (literally, child hatchery) at the exposition. To his surprise the *Kinderbrutanstalt* became the subject of music-hall jokes and cabaret songs, and thousands of visitors thronged the exhibit. Rather than just break even, Couney made a substantial profit. The exhibit also proved a technical success: According to Couney, all the infants on display survived.

In 1897, encouraged by his success, Couney moved to the Victorian Era Exhibition at Earl's Court in London. He immediately encountered resistance from the medical community. British doctors, scandalized by the notion of premature infants' being publicly displayed, refused to send Couney any, even though they themselves could offer the infants no other assistance. Relying on his association with Budin, Couney arranged to have three wicker baskets full of newborns sent across the Channel from Paris. Like the *Kinderbrutanstalt*, this exhibit was tremendously popular and a huge financial success; on one day alone it attracted thirty-six hundred visitors.

Unfortunately, Couney's success encouraged competitors, who were neither as qualified nor as scrupulous, to open incubator exhibits in London. These competing exhibits incurred the wrath of the British press, which had initially supported Couney's work. One editorial declared that "we should at once protest that human infirmities do not constitute a fit subject for the public showman to exploit. . . .What connection is there between this serious matter of saving human life and the bearded woman, the dog-faced man, the elephant, the performing horses and pigs, and the clowns and the acrobats?"

"The Infant Incubators" was Coney Island's oddest and at times most popular attraction.

Soon thereafter Couney, accompanied by his incubators, traveled to the United States to establish an exhibit at the Omaha Trans-Mississippi Exposition of 1898. That same year Budin was appointed to a position at the Clinique Tarnier in Paris, the first medical facility dedicated to the treatment of premature infants. Using the incubator method, Budin reduced the mortality rate for infants weighing less than two thousand grams (about four and a half pounds) from 98 percent to 23 percent. In 1900 Couney returned to France to work the Paris World's Fair.

The next year found him back in the United States, setting up an incubator exhibit at the Buffalo Pan-American Exposition. America offered the exhibitor substantial opportunities: at the time, there was a major exposition almost every year, and many visitors, wary of the notion of seeking pleasure for its own sake, welcomed the presence of educational shows on exposition midways. Couney decided to remain over here.

In 1903 Frederic Thompson, a showman who had operated an exhibit at Omaha and helped design the Buffalo midway, embarked on an ambitious project at Brooklyn's Coney

Couney with one of his charges at the Pan-American Exposition in Buffalo, New York, 1901.

BUFFALO AND ERIE COUNTY HISTORICAL SOCIETY, BUFFALO, N.Y.

Island, which (in the words of *The New York Times*) had "become famous for catch-penny schemes, toboggan slides, wheels big and small, and dance halls of more or less repute." During the winter of 1902–03 three thousand workers built Luna Park, then the most elaborate amusement park ever constructed, decorating it with a quarter-million electric lights. Thompson persuaded Couney to open a permanent exhibit at Luna Park, and although Couney eventually established incubator exhibits at amusement parks in Chicago and Atlantic City and demonstrated his technology at forty-three world's fairs, Coney Island would be his base for the remainder of his career.

Couney's exhibits had a survival rate unsurpassed at any medical facility anywhere.

Couney's first American incubator exhibit, at Omaha in 1898, was so successful that he soon set up permanently at Coney Island.

The Coney Island infant-incubator exhibit was, for all practical purposes, a small hospital. An array of a dozen or so iron-and-glass incubators (the number varied) were heated by hot-water pipes connected to a central boiler. Air flowed into each unit through a triple filtering system from a forty-foot flue, believed to be above the "dust line." Drawing air through small exhaust fans mounted on the incubators, they provided a complete change of atmosphere every five seconds. A staff of trained nurses attended the infants, who rested on fine wire hammocks inside the incubators; wet nurses fed those strong enough to suckle, while the others were given mother's milk with an eyedropper. A baby's stay might last a few weeks to a few months, depending on how well it developed.

People greeted the attraction with a mixture of curiosity and naiveté. Early promotional literature for one of Couney's exhibits observed that "the public has peculiar notions concerning this institution [because] the word incubators, to the uninformed, is apt to suggest something more or less than the mere rearing or preserving of life." As a result, visitors often asked how the babies got into the incubators and where Couney had obtained the "eggs." On occasion someone would ask to have sexual intercourse with the incubator device—a truly astonishing example of the era's faith in technology. One infertile woman wrote to the American Medical Association certain that Couney could help her conceive.

Often the hardest task Couney's lecturers faced was simply convincing skeptical sideshow patrons, fresh from viewing bearded ladies and sword swallowers, that the babies really were alive. But whatever the motivation, visitors came in droves, paying a twenty-five-cent admission fee—two and a half times the going rate for Coney's other attractions—to see the display. Most were women, and the exhibit seemed to have especial appeal to childless women. Many customers returned daily or weekly to follow the progress of a particular infant; one regular came to Couney's incubators every week for thirty-seven years.

A journalist, reporting on a visit to Couney's exhibit at Luna Park, observed that "the babies proved to be very little ones, and very good and clean, and all were asleep in their small crystal houses which are kept at just the proper temperature to make the occupants grow and keep good and healthy. And the boy babies were tied with blue ribbons and the girl babies with pink, and the audience, mothers for the most part, discussed their relative merits and compared them with other babies of their acquaintance, including vivid memories of their own."

After Couney's arrival at Coney Island, the Brooklyn Society for the Prevention of Cruelty to Children launched an investigation into his activities. It was a serious matter; subsequent investigations by this organization would result in the suspension of several Coney Island sideshows, including the public display of a pair of eleven-year-old Siamese twins. The society thought it outrageous that Couney was exhibiting infants for a fee and thought his procedures might be improper, but he convinced his critics that the admission charge was necessary to finance the care provided to the infants. (It also, he said, "bars the disinterested, undesirable class of visitors.") As for his procedures, Couney pointed out that he offered better care than any facility in the United States. In the end the society lodged only one substantiated objection: Couney did not

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A nurse feeds an infant with a nasal spoon at St. Louis in 1904.

Couney's daughter Hildegard holds a preemie at Atlantic City in 1934.

hold a license to practice medicine in the United States. He quickly obtained one.

Couney's activities certainly stretched the bounds of conventional morality, and the doctor perpetually struggled to maintain an air of professionalism at his facility. To preserve some semblance of decorum amidst Coney Island's mayhem, Couney developed and strictly enforced ethical and procedural guidelines for his operation. The most draconian applied to the lecturers who guided visitors through his exhibits; the introduction of a single joke into their presentations would result in immediate dismissal. On one occasion, after being told that the infants were attended by both trained nurses and wet nurses, a visitor asked how long it took for the former to become the latter. "That depends on how careful she is," the lecturer replied, and although he was considered the exhibit's best, Couney promptly fired him. Similarly, any nurse who accepted a gratuity or gift from a parent or visitor was subject to discharge. "We run the place absolutely ethical," Couney told his staff, "not like a sideshow."

Always concerned over the quality of the milk being fed to the infants, Couney hired a cooking staff to prepare meals for his wet nurses. Any one of them caught eating a hot dog or grilled corn from local concessions would be immediately fired. Fearing that anxiety could taint their milk, he also tried to protect the nurses from stress, offering advice, money, and gifts and sponsoring contests (the woman whose infants gained the most weight each week won a pair of silk stockings).

Couney also maintained strict procedures for dealing with the parents who brought infants to his facilities. In their presence the baby received an identification necklace, which remained undisturbed until the infant was reclaimed. The doctor never accepted or offered any payment for treating an infant, and the identities of children and parents were kept in complete confidence. Couney accepted children from "every station of life, high or low, rich or poor, black or white," because "this institution for the preservation of infant life makes no distinction"—a remarkably progressive policy in a time when most places of amusement were segregated by law or custom.

When Dreamland, a grandiose rival to the highly successful Luna Park, opened at Coney Island in 1904, Couney established a second facility there. The infant incubators became the new park's most popular attraction, but the opportunities offered by Dreamland almost turned to tragedy. The night before opening day in 1911, fire leveled Dreamland's wood-and-plaster edifices, and while the blaze roared through the park, the eleven occupants of its incubators were rushed across Surf Avenue in baskets heated with hot-water bottles to the Luna Park incubators. Some infants had to double up for the evening, but not one was harmed.

In February 1907 Couney's wife, Annabel, gave birth six weeks prematurely to a three-pound baby girl. The exhibits

TOP: MISSOURI HISTORICAL SOCIETY; BOTTOM: UPI/BETTMANN

were closed for the winter season, the incubators in storage. Couney kept his daughter alive while friends rushed to retrieve an incubator. Hildegard Couney survived to become a registered nurse and one of her father's principal assistants. Persistent but apparently unfounded rumors suggested that Hildegard was actually an abandoned incubator exhibition baby adopted by Couney. And indeed, Couney often had difficulty getting parents to accept babies reared in his incubators, perhaps because the parent-child bond had not been able to form.

In time Couney gained a following for his keen showmanship, and other sideshow proprietors often sought his advice. He also developed the ability to generate publicity with staged events, such as graduation ceremonies and reunions for his former patients. But on one occasion his instincts failed him. On May 28, 1934, Elzire Dionne gave birth to five infants—identical quintuplets—in Ontario, Canada. The babies, with an aggregate weight of twelve pounds, were being kept alive with heated bricks and flatirons when a representative of William Randolph Hearst offered Couney a large salary and payment of all expenses if he would fly to Canada with his incubators (accompanied, of course, by Hearst's reporters and photographers) and assume care of the Dionne children. Couney declined, certain that the infants could not possibly survive—a belief well supported by his personal experience with multiple births: of the eighteen sets of triplets Couney treated over the years, only six complete sets survived.

Doctors from around the nation rushed premature infants to Coney Island for treatment.

But the children did survive—the first known set of quintuplets to outlive infancy—and the pediatrician responsible for their early care, Allan Roy Dafoe, became a celebrity along with his charges. "I was wrong," Couney later lamented. "This case may not repeat itself in a millennium."

Photographs from a 1904 souvenir program show the different sections of Dr. Couney's extremely popular exhibit of incubators at Dreamland.

Eventually the public's interest in Couney's exhibitions began to wane. Extension of the subway to Coney Island in 1920 had guaranteed continued crowds, but they spent less money. Couney lowered his admission fee to 20 cents in 1937, but by 1939 the overhead had risen to $140 a day, requiring seven hundred daily visitors just to break even. "Thirty-five years ago I could do more business with sixty thousand visitors than I can do with five hundred thousand now," Couney told an interviewer in 1940. "Coney Island is so degraded . . . that people bargain to see my babies."

During the course of his career, Dr. Couney saved the lives of better than 80 percent of the roughly 8,000 infants brought to his facilities. Moreover, he gained widespread respect from American physicians. Doctors in the New York City area, and eventually the entire nation, rushed premature infants to Coney Island for treatment. As articles about incubator technology crept into American medical journals, they cited Couney's exhibits by way of illustration and comparison. Yet despite his achievements, Couney was for a long time unsuccessful in fulfilling his original mission, as envisioned by Budin in 1896, of generating adoption of the incubation of premature infants.

Why was the medical profession so slow to adopt Couney's methods? Mainly because the mortality rate was still so high for full-term infants that they seemed the most urgent candidates for concern and research. The overall infant mortality rate was reduced from 126 deaths per 1,000 births in 1900 to approximately 80 by 1926. During this same period the mortality rate for premature infants stayed virtually unchanged. As a result, by 1925 prematurity had become the largest cause of infant mortality, accounting for 36 percent of all deaths in the first week of life. The problems of prematurity, as well as the methods Couney had been using since the 1890s, finally began to attract greater interest.

In 1922 Dr. Julius Hess of Chicago published the first textbook dealing exclusively with the treatment of premature infants. Couney helped prepare it. Seventeen years later—and thirty-six years after the infant incubators made their debut at Luna Park—Cornell University's New York Hospital established a training and research center for premature infants. It was hailed as "the first of its kind on the Eastern seaboard," but it differed little from Couney's facility.

Couney considered the opening of Cornell's center a personal victory. "I made propaganda for the preemie," he proudly told his nephew, and although he still had eleven years to live, he added, "My work is done." He closed his Coney Island exhibit in 1943. ★

Gary R. Brown wrote "Sawing a Woman in Half" in the Winter 1994 issue.

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Henry Ford's Big Flaw

WHY WAS HE SO EXTRAORDINARILY CREATIVE—AND THEN SO EXTRAORDINARILY UNCREATIVE?

BY JOHN M. STAUDENMAIER, S.J.

PEOPLE OFTEN WRITE ABOUT HENRY FORD AS IF HE WAS A VERY ODD DUCK unlike the rest of us—an odd duck who had so much money he could get away with things. I think of him as a very ordinary duck, the difference being that after his early years he had so much money that he could act out impulses that we all may have but can't possibly obey. I think his very similarities to us make it instructive to follow Henry Ford through some of his history.

If you look at pictures of early Ford factories—the Mack Avenue plant, opened in 1903, and the larger Piquette Avenue plant, opened the following year—you'll find that they were very typical for their time. Ford was making cars like everyone else, at stationary work stations to which parts and materials were brought for a host of different operations. But by 1914 Ford's team had radically transformed the stationary Piquette Avenue process into the now world-famous moving assembly line, where each worker did a single task while the emerging car moved past the work station. The change took about eight years,

Ford looks the picture of confidence in 1912, when th assembly line was emerging

ALL, UNLESS OTHERWISE NOTED: COLLECTIONS OF HENRY FORD MUSEUM AND GREENFIELD VILLAGE, DEARBORN, MICH.

Between 1906 and 1914 Ford and his engineers pulled off one of the great creative revolutions in technological history.

from 1906 through 1914. Those eight years represent one of the great creative revolutions in technological history. Why did it happen at Ford?

It happened there in great part because Henry Ford assembled an extraordinary team of engineers. Their ferocious work habits look like a form of play. They routinely ran big risks, changed their minds, debated one another, all because they were reaching for a production system that would solve a problem they had created for themselves—the immense popularity of the 1908 Model T.

The Model T is probably the most successful single technical design in American history. The T's design fit the context of its time almost perfectly. In 1904 only 7 percent of the roads in the United States were paved. The other 93 percent were basically impassable after a hard rain and deeply rutted when dry again; that meant a car had better be lightweight and extremely durable and have a high center of gravity. Also, since there was virtually no infrastructure of service stations or auto mechanics, the car had better be simple enough for most users to repair. The T was famous for precisely these qualities.

A ragged cluster of Model R's and S's receive finishing touches at the Piquette plant, 1907 or 1908.

In his early years Henry Ford fought with stockholders about what kind of car to make. The conventional wisdom held that the primary market for cars must be the well-to-do, such as doctors, politicians, and successful clergymen. Ford wanted to build a cheap car, which would have a small profit margin but sell to a very broad range of people. And sell it did. After three extraordinarily successful initial years, the Ford team stopped trying to preplan annual sales, assuming instead that they would sell every T they could make more or less as fast as they could make it, a situation that held into the twenties. That gave Ford both a tremendous incentive to manufacture more quickly and the resources to invest in the production process.

The creation of the moving line took six years because the Ford team worked and reworked the moving line's most bedeviling problem—materials handling. A moving assembly line can move at a constant speed only if every component that goes into it pours in at that same constant speed. When the product is a precisely assembled machine with thousands of subcomponents, the challenge of integrated flow becomes enormous.

By 1910 they had moved into the huge Highland Park plant, a factory where logistical arrangements became the benchmark for future manufacturing. Highland Park had four-story manufacturing centers alternating with one-story machining centers, rail yards where they brought in materials, and an elegant executive office building. But even more elegant than the office was the power plant housing the gas turbines that generated electricity for the factory. For Henry Ford, the power plant was clearly a work of art. Enormous plate-glass showroom windows faced Woodward Avenue; everything inside—tile floor, brass fixtures, massive dynamos—was kept spotless.

Ford's celebration of this workaday facility provides a clue for understanding technical genius not only at Ford but wherever it occurs. You can think of it as having three major components. The first looks inward. Ford engineers paid close attention to the technical problems they would have to solve to achieve the moving line, in terms of machine-tool design, materials handling, and so on. Any time anyone has ever designed a technology well, part of what they have had to do has been to get the internal workings right. In any research and development, there must come a point where you stop debating about your goals, close the doors on distractions, and work on getting the design right.

The second component is where the showcase power plant comes in. Good engineering requires a capacity for pride in the beauty of technical achievement, a sense that the internal design work just mentioned is worth displaying to the world. The celebration that accompanies really good engineering is crucial because it puts the engineer's imagination in touch with the larger societal context within which every technology ultimately operates. Design work that is cut off from its host society quickly loses the creative touch.

That's the point of the third component, which I call "back-and-forth consciousness." The same people who focus inward must also open outward to the larger world. As I mentioned, Ford's engineers designed the T in response to poor roads and a weak infrastructure, but it could also be argued that Henry Ford's insistence on a cheap car for the masses flowed from a very sophisticated intuition about what we now understand as the American love affair with the automobile. In 1900 only about four thousand cars were sold, yet many of the short popular films of the period treat automobiles as the fulfillment of powerful fantasies. Ford grasped, perhaps better than anyone else of his time, how cars excited people.

We see, in short, a very healthy technological aesthetic at the heart of the Model T and assembly-line achievement between 1906 and 1914. It blended precise reasoning with intuition about the larger world. Gradually, however, the balance required to hold these elements together deteriorated. The trouble began at the height of Ford's accomplishment, in 1914, when events conspired to turn Henry Ford from a successful engineer into a symbolic hero, almost a god figure. The first event was the completion of the moving line. Much more important on the symbolic level, however, was the introduction of what came to be known as the five-dollar day.

During the first decade of the century the United States was absorbing more than 800,000 immigrants each year into a population of about 80 million. They came mostly from Eastern and Southern Europe, with scant industrial skills and what most Americans of the time felt were strange religions and customs. How to blend this flood of cheap but untrained labor into a sophisticated production process? The Ford team radically restructured work assignments, simplifying the great majority of them so that new workers could be trained in as short a time as possible. The moving line not only sped production, it also reduced the worker's role to repeating a single set of actions over and over. Immigrant workers, together with more highly skilled American workers, hated the moving assembly line as a mind-numbing and nerve-racking ordeal. "Forditis"

A thousand Model T Fords—the work of a single shift—line up at the Highland Park factory, 1913.

became a name for the miscellaneous ailments that resulted. In 1913, as the line neared completion, worker turnover at Ford reached the astonishing rate of 370 percent.

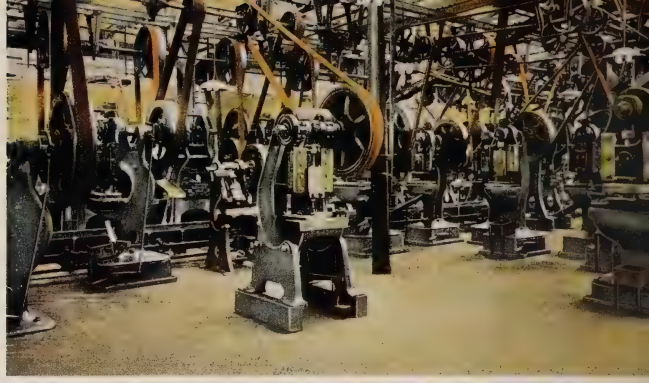
The Ford people addressed the problem head-on and announced, in January of 1914, that the workday would be shortened from nine to eight hours as the company hired new workers and moved to three 8-hour shifts, and the workers' daily wage would double from an average of roughly $2.50 to $5.00.

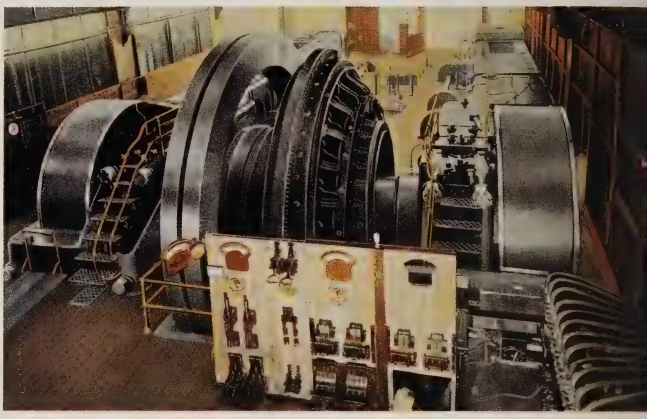
It is hard to convey the awe with which Ford was treated by the press when this happened. In effect he was saying, "I am not being a fool and simply raising wages; I am sharing the profits of a very profitable enterprise, because you can't make a car for the masses when the masses can't afford the car, and there's no point in having a work force that is ground down and dirt poor."

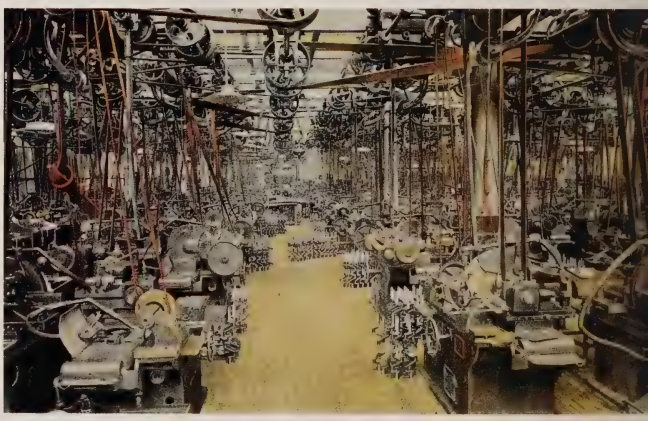
Doubling wages while cutting work hours was the main way the Ford people responded to that 370 percent turnover of 1913, but they did another, less publicized, thing too. In 1914 Ford founded the Ford Sociological Department. A worker could qualify for the five-dollar day only after his or her home was inspected by a member of the Sociological Department. The inspectors came with an interpreter, because the worker usually didn't speak much English, and they examined the home for cleanliness. They checked whether the employee was legally married and whether he kept boarders, which was frowned on. They checked on whether the employee was in debt, whether he drank too much, and on and on.

Why was that? Was that part of Henry Ford's technological aesthetic? Did he have to do that to stop the turnover of workers? No. If you shorten the workday and double the salary, that ought to be plenty. But he had some other feeling that I think came partly from his sense of what it must be like to be an immigrant. There were loan sharks out there. Immigrants didn't know how the country worked and had to learn English. Ford had English-language schools full of immigrant workers. So did many other companies.

Henry Ford wasn't alone in intruding into people's lives to tell them how to live and how to be American;







Postcard views of Highland Park, in 1917: from top, the pressed-steel department, where small parts were made; one of seven 6,000-horsepower gas-turbine engines in the powerhouse; the crankshaft-grinding department, with some of the plant's fifty miles of belting; and the Ford English school, on the factory lawn.

that was common enough around the United States at that tumultuous time. But it may have been especially easy for Ford as he grew to heroic stature in the public eye. Amid the enormous success of the Model T and the moving line and the five-dollar day, he and his team were shifting their consciousness.

They focused more and more intently on the technological genius they had already shown—particularly in materials-handling and production processes—and spent less and less of their energy reading the changing character of their time and their society. They were losing that back-and-forth between the technology itself and the larger cultural context. They were going into a phase of technological obsession with something truly beautiful and magnificent. The obsession was embodied by the most famous of Ford's factories, begun during World War I, River Rouge.

By the late 1920s Ford's River Rouge factory encompassed more than a hundred buildings sprawled over two thousand acres. Boats came into a turning basin to unload their goods. Scores of miles of rail lines crisscrossed the property. Henry Ford envisioned an integrated system that controlled access to all the components of the automobile and brought them together at the Rouge. The Ford Motor Company bought 400,000 acres of hardwood forests in upper Michigan, built its own lumber-processing plants there, and bought its own boats to ship the lumber. It bought iron mines in upper Michigan and made its own steel. It bought a rubber plantation in Brazil to produce its own rubber. It made its own glass. And so on.

The great business historian Alfred Chandler calls this grandiose effort the biggest single business mistake in United States history. Automobiles are far too complicated for anyone to control all their elements. An automaker ought to have healthy relationships with suppliers for a lot of those things and ought to concentrate on the main business, which is making the finished car, not making steel and glass and rubber.

Henry Ford simply became obsessed with controlling his entire environment. In 1916 a pair of stockholders sued him for keeping dividends too low while plowing the profits back into company expansion. He responded by resigning as president of the Ford Motor Company in favor of his son Edsel and announcing that he was going to start a new company, building a new car that would be better than the Model T. This threw his stockholders into a panic. He had a dummy front company set up, and it bought up all their shares. In July 1919 he became the sole owner of the Ford Motor Company. By this point he did not want to be disagreed with at all.

This was the same Henry Ford who in 1906 or 1908 had been right in the thick of a supple engineering team where they disagreed all the time and continually criticized one another and made mistakes. Something had hardened in him; what had been almost playful became obsessive. This manifested itself in many ways. For instance, the Highland Park factory, opened in 1910, faced right onto city streets, so that when the workers went to lunch the company had no say in whom they talked to—labor organizers or anyone else. River Rouge, contrastingly, sat out in the middle of nowhere with no public access. It had a fully fenced perimeter and could be entered only through guarded gates.

The entrance itself was Ford property, as was demonstrated in 1937 in the famous battle of the overpass, in which the United Auto Workers, whose tactics had just been declared legitimate by the United States Supreme Court, tried to leaflet on the stairs and were brutally beaten up by Ford's ad hoc security police.

Amid the enormous success of the T and the moving line and the five-dollar day, he and his team shifted their consciousness.

Why did Ford fence in River Rouge? I believe it was part of the gradual hardening of the boundary around his work. Henry Ford was no longer interested in being interrupted by people from the outside with whom he differed. He fired a host of very creative people because they disagreed with him. He had Harry Bennett, his henchman, fire one man by asking him to lie on the running board of a car and listen to the engine, then driving the car out through the gate and spinning around so the man fell off. The car roared back in, and the guards at the gate told the man, "You're fired." They were playing hardball at Ford.

In 1932 and 1933 the Mexican artist Diego Rivera painted his famous murals of River Rouge, in the Detroit Institute of Arts. Rivera fell in love with the River Rouge factory and admired Henry Ford. He called Ford the greatest artist in the world. While sketching at River Rouge, he said, "I thought of the millions of different men by whose combined labor and thought automobiles were produced, from the miners who dug the iron ore out of the earth to the railroad men and teamsters who brought the finished machines to the consumer, so that man, space, and

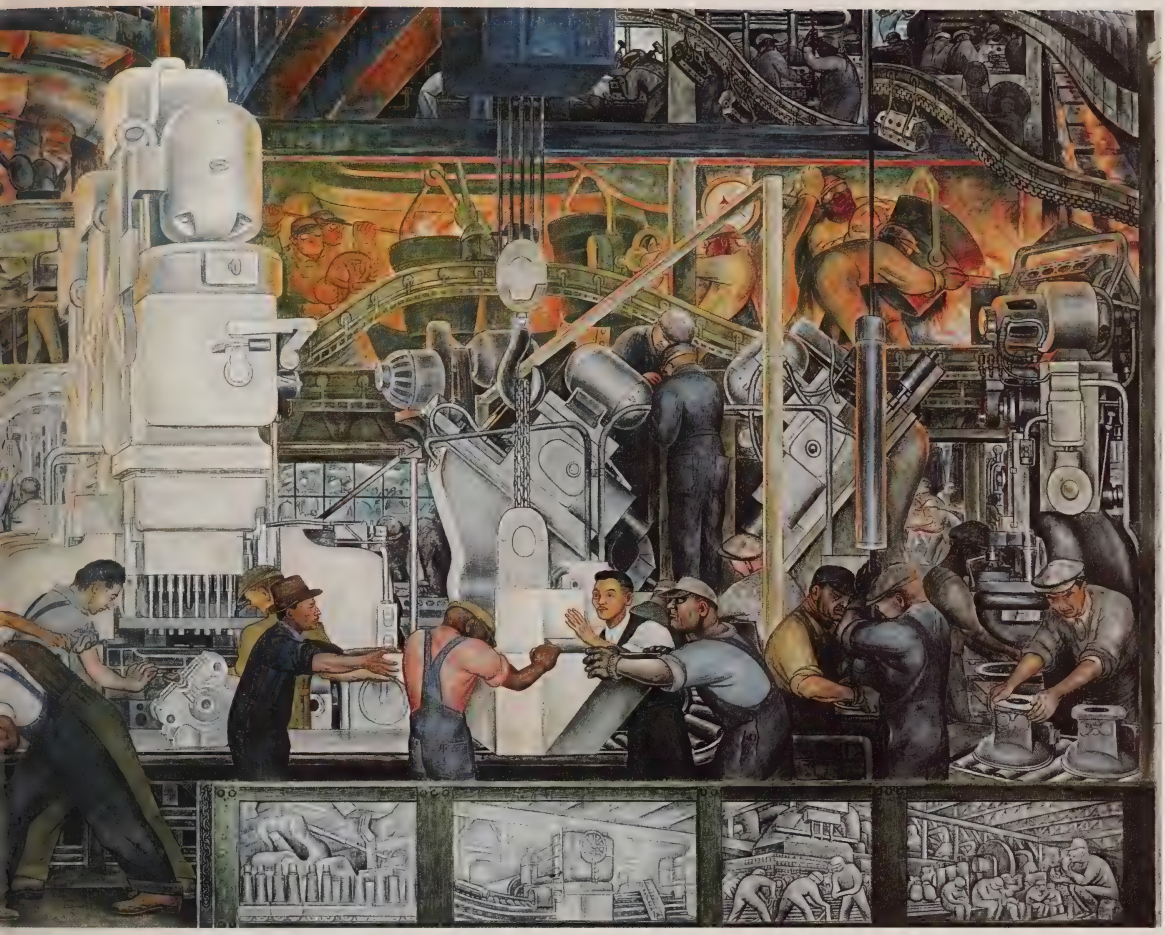
ALL OPPOSITE: AMERICAN HERITAGE COLLECTION

Above, a detail of Diego Rivera's north-wall mural at the Detroit Institute of Arts. At right, Ford and his son Edsel examine a model of River Rouge, 1937.

time might be conquered, and ever expanding victories be won against death."

Diego Rivera was mesmerized by the technocratic spirit he found in Ford's production system, but he and Ford had very different approaches to it, as becomes evident if you look closely at Rivera's work. Rivera's large north wall panel is very sophisticated: the lines of drill presses form boundaries that divide the huge mural—thirty-five feet wide—into three areas. But these are a sort of boundary very different from Ford's fenced perimeter. Rivera's boundaries are continually permeated by lines of color and conveyor belts and workers who move back and forth as creative forces along with the machines. These

TOP: DETROIT INSTITUTE OF ARTS



are boundaries that give you a sense of visual order, but they're permeable. They're messy. They have flow running right through them.

You could say that both Ford and Rivera loved what was inside the technological box, inside the plant. But when they stepped back and perceived the border around the box, they saw very different things. By 1925 Ford had a very tough wall. He insisted on controlling what was inside, and he even tried to reach out and control what he could on the outside. The five-dollar day was an early hint of his need to control. He didn't just want the workers to follow orders in the factory; he wanted to make sure they behaved at home too. He had by now such a sense of his genius that he wanted to impose that genius on a larger reality.

Indeed, the more obsessed Henry Ford and his people became with their own technological genius and the beauty of their creations, the tighter they made the boundary.

Rivera pictured extremely permeable boundaries in the plant; by 1925 Henry Ford actually had a very tough wall.

By the late 1920s Henry Ford had retreated wherever he could from interaction with the larger world. He even created a whole new world that he could dominate, a private world now called Henry Ford Museum and Greenfield Village. He began to buy antique technologies in the early twenties, and the complex was dedicated in October 1929 at a lavish celebration of the fiftieth anniversary of Thomas Edison's first successful light-bulb experiment.

Greenfield Village with all its exhibits takes up about 85 acres, and the museum, an enormous structure, covers

Ford became obsessed with controlling his environment. He even created his own private world —Greenfield Village.

12 acres. I've recently interviewed people in their seventies and eighties who went to work at Greenfield Village as guides in the early 1930s. One of their rules was that when Mr. Ford was around, visitors should be kept away from him. I asked one man recently what that was like. He said, "It wasn't that hard. Mr. Ford would show up mysteriously, and he was very good at being on his own, and usually we would notice him only at a distance."

The Sir John Bennett Jewelry Store in London (left) so caught Henry Ford's fancy that he bought it and had it disassembled, packed up, and moved to Greenfield Village in the winter of 1930–31.

Henry Ford often went to Greenfield Village alone at night. He loved repairing watches. He had three craftsmen repairing watches in the Sir John Bennett Jewelry Store, which he had bought in London and reconstructed in the Village. Sometimes in the middle of the night, the guides tell me, Ford would go up to the watch shop's second-floor repair room and remove some watches and not tell anybody. The workers would come back the next day and they couldn't find the watches. They were his watches. It was his place.

He prowled the grounds of Greenfield Village almost like the Phantom of the Opera. He reminds me of a dream I had as a child. I lived in a town of about twelve thousand, and we had a big department store covering a city block and three stories high. I used to imagine sneaking in there on the weekend all by myself. I'd sleep in one of the new beds, cook on one of the new stoves, using a frying pan from the housewares area and food from the grocery area, and I'd wear clothes from the clothing area and shoes from the shoe department.

Millions of us have a fantasy that we can control a universe of goods. That's the urge that my childhood department store and today's malls are designed to satisfy. They offer a fantasy world—hundreds of thousands of dazzling new products in an untroubled environment. People can't make speeches in malls the way they do on street corners. In fact, a mall is a lot like Henry Ford's River Rouge and Greenfield Village, except that the consumer, rather than Henry Ford, is king.

Henry Ford had a Cotswold cottage shipped stone by stone from England and rebuilt at Greenfield Village at a cost of a million 1927 dollars. I talked to a man who had worked there. He told me about one day when Henry and his wife, Clara, came in. Ford went to the back yard and was looking around the gardens when Clara, inside the house, looked at a hutch and said, "I don't think it looks good where it is. Let's move it over there." She and the interpreter moved it across the room. A little while later she went out into the garden and Henry came in, and he asked who had moved the hutch. Then he moved it back.

The dream of a world where no one will disagree with you about anything, where you have all the resources to live out all your fantasies, is a dangerous daydream. It is, I believe, what can happen when we grow tired of the labor of creativ-

At Greenfield Village, the jewelry shop was put back up in telescoped form to fit the scale of its surroundings.

ity. The kind of environment they had at Ford around 1914, where the team was doing so much right, including that crucial thing I called back-and-forth consciousness, is a genuine technological form of beauty. It blends precision and purposefulness and focus and discipline and achievement with intuition and suppleness and what I would call interruptibility, the ability to be surprised and educated by large and small realities. That, I think, is the most healthy technological aesthetic.

He became more and more a prisoner of his own triumphs. Something like that can happen to technologists today, or at any time.

In 1927 Ford rides in a milestone Model T hardly changed from the first one built in 1908.

As Henry Ford lost his capacity to be educated by a world larger than his own domain, his genius rigidified. He became more and more a prisoner of his own technological triumphs. Something similar can happen to sophisticated technologists today, or at any time. The supple ability to blend technical design expertise with perceptive intuitions about the larger world, as technological creativity requires, may be threatened for many people today, I think, because two of our most powerful mythologies, which made sense of American technological creativity throughout the twentieth century, have lost their relevance. The first is the myth of the empty land, the myth of the American wilderness to be shaped and filled for human purpose—bridges to be built and homes to be constructed and schools and churches and water systems and electric power utilities. As much truth as that myth has had in the past, it has become much less helpful in the last twenty-five or thirty years, since we don't have endless resources any more. Pollution has become a far more pressing concern than settling a wide-open frontier.

The second myth is younger. It is the myth of the evil enemy, which, as we know, was born in World War II. I was five when the war ended, and I remember that I thought for a while that Stalin was Hitler's son. The reason, of course, was that he looked like Hitler and he came after Hitler as another completely evil enemy. The idea of the pure enemy has gotten less useful too. Russia certainly isn't that enemy any more.

In other words, myths that give us purpose and identity so that we can figure out who we are and what to do can become obsolete or, as in the case of Henry Ford, can impalpably shift into very different myths. Ford started out with a powerful conviction about what America wanted: the Model T. Then, having been so right, he forgot how to be wrong.

Certainly we always need patience, hope, imagination, humor, and a willingness to fail and to disagree, and it is always a challenge to nurture these qualities. Only some of the virtues we need—in engineering or in anything else—are those where we already know our goal and we set ourselves to achieve it with courage, energy, and clear-eyed purpose. We also need the virtues where we let ourselves receive from the larger realities around us. We all need them, and they are what Henry Ford lamentably and at great cost gave up, at the peak of his success. ★

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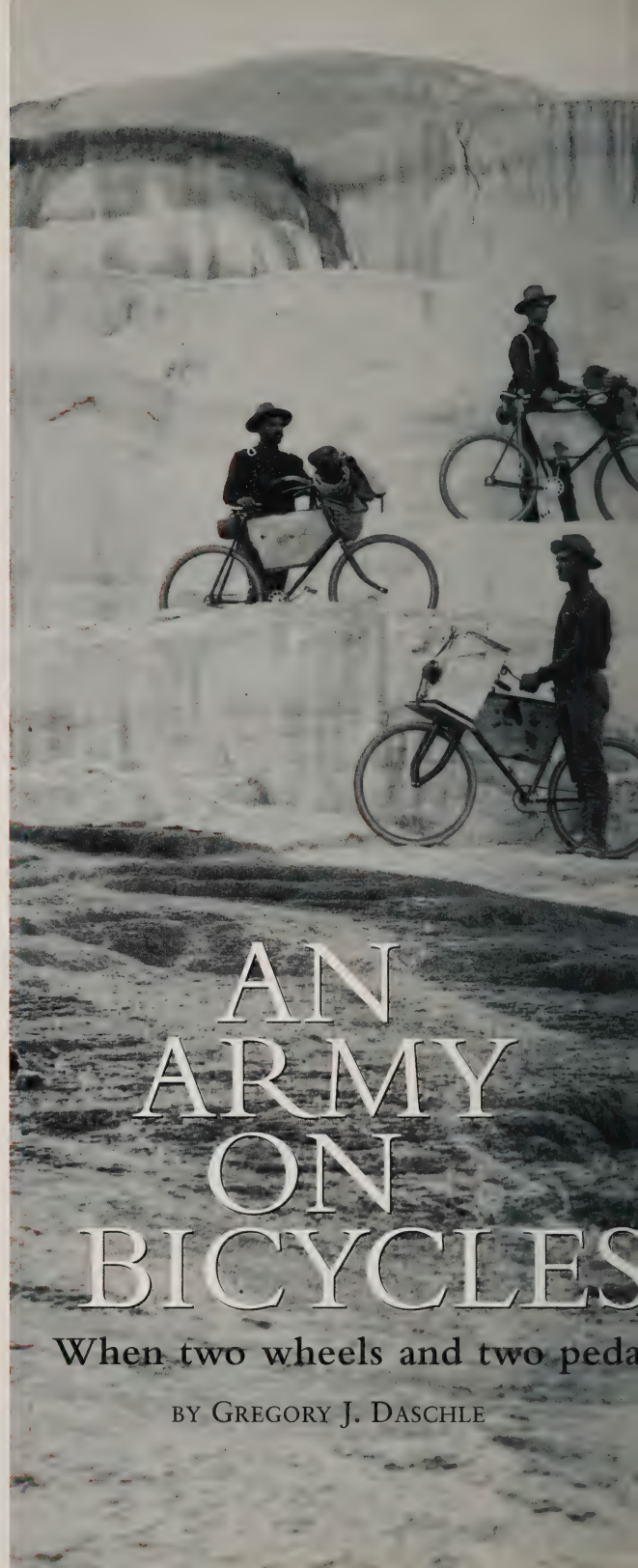

AN ARMY ON BICYCLES

When two wheels and two peda

BY GREGORY J. DASCHLE

Toward the end of the nineteenth century, as bicycles became more reliable and easier to ride, various Western countries experimented with using the new device as a military tool. Italy was the first, putting crack sharpshooters on wheels in 1870. By 1887 the French Army had soldier cyclists; it later developed a folding bicycle weighing only twenty-five pounds that could be carried in a backpack. Cyclist sections were formed among British volunteer forces in 1888; by 1894 they numbered 5,100, with a planned increase to 20,000. The United States, in keeping with its customary post–Civil War inattention to the military, did not include bicycles in the country's defense scheme until 1891, with a forty-man National Guard unit in Connecticut.

To a young West Point graduate named James A. Moss, this conservative effort was not enough. He had a powerful urge to prove that bicycles could be valuable to the U.S. Army. Lieutenant Moss was stationed at Fort Missoula in Montana, where his chief duties consisted of fighting Indians. His enthusiasm for bicycles was based on their many advantages over horses.

Bicycles were cheaper, did not eat, and required little care. They made almost no noise and were less conspicuous. They raised little dust, and unlike a horse's hoofprints, a wheel track would not betray its direction. Bicycles needed no caretakers to stay with them, thus freeing more soldiers for the battlefield. And on adequate roads cycles were surprisingly faster than horses. When there was a greater need for speed than numbers, as in the taking and holding of passes, bridges, or other strategic places, wheelmen could be very valuable.

Moss conceded the horse's superiority under some conditions, including bad roads and rainy weather. And of course bicycles could never replace horses in the cavalry's main function—the charge. Still, while the Army had experimented with using bicyclists to carry messages, Moss noted that there had been very little effort to apply them to troop movement. He was eager to give the idea a try, and in 1896 he managed to secure the support of Gen. Nelson A. Miles, command-

The 25th U.S. Infantry Bicycle Corps trains at Yellowstone, October 1896. Lieutenant Moss is at top.

vere the cutting edge of military-transport technology

HAYNES FOUNDATION COLLECTION, MONTANA HISTORICAL SOCIETY, HELENA

Inset: Lieutenant Moss in 1894. Above: The route to St. Louis, from Moss's official report.

er in chief of the Army.

General Miles, an avid wheelman himself, had been involved with some of the Army's first bicycle experiments. In one, begun on May 18, 1892, he sent a message from his headquarters in Chicago to Gen. O. O. Howard in New York. Through heavy rains, bicycle relays covered the 975 miles in four days and thirteen hours. Moss referred to General Miles as "The Patron of Military Cycling" for these efforts and for his recommendation that the Army maintain a regiment of cycle infantry at Fort Missoula. On this authority the 25th U.S. Infantry Bicycle Corps was organized in July 1896 under the command of Lieutenant Moss.

Besides Moss, the original corps consisted of a sergeant, a corporal, a musician (to play reveille, taps, and so forth), and five privates, among them a cycle mechanic. After the corps was established, Moss began holding daily practice rides of fifteen to forty miles and exercises involving fence climbing and stream crossing. Soon the men could ford three-foot-deep streams and scale nine-foot fences with little difficulty.

A round trip to Lake McDonald in the nearby Mission Mountains presented the first major challenge for the 25th Infantry wheelmen. Although a violent rainstorm impeded their progress, the men managed to cover the 126 miles in twenty-four hours of actual pedaling. General Miles was impressed and gave the go-ahead for a trip to Yellowstone Park.

On that exercise the corps again proved its mettle, covering the 791-mile ride in only 126 traveling hours—an average of six and a quarter miles per hour, despite bad roads and the eighty-pound weight of the laden bicycles. Of all the physical hardships, wind proved to be the worst. Moss noted that even when conditions did not allow pedaling, foot travel was easier than usual because men could wheel their packs instead of carrying them.

In view of these successes and others, General Miles recommended to Secretary of War Daniel S. Lamont that Moss be allowed to lead his troops on a twenty-eight-hundred-mile roundtrip to St. Louis the following summer. St. Louis was chosen as the destination to provide the most severe test possible, with a broad variety of altitudes, climates, and road conditions, including the rocky roads of Montana, the sand roads of Nebraska, and the clay roads of Missouri.

For the St. Louis expedition the corps increased in size to include a surgeon, an additional corporal, and eleven more privates. Their average age was twenty-seven, and except for the surgeon and Moss, all the men were black. A *Daily Missoulian* reporter, Edwin H. Boos, accompanied the corps on its journey. His reports were sent to newspapers across the country. The Spalding Company furnished chain-driven bicycles specially outfitted to Moss's specifications with extra-heavy forks and crowns, gear cases, steel rims, tandem spokes, and streamlined storage areas.

The corps left Fort Missoula at 5:40 A.M. on Sunday, June 14, 1897. Boos reported: "They presented a pleasing picture and their progress will be watched with interest from one end of the nation to the other." The men indeed looked sharp in their canvas

NATIONAL ARCHIVES. INSET: U.S. MILITARY ACADEMY ARCHIVES

Moss, at left, and his enlarged corps prepare to set out for a 2,800-mile roundtrip to St. Louis.

knickerbocker trousers, blue gingham shirts, and campaign hats. Rifles slung across their backs and gleaming white bike packs completed the spectacle.

The first day's ride gave a good sample of their impending trials. A violent afternoon thundershower turned the roads to gumbo, choking the corps's wheels with mud. Alternately riding and carrying the bicycles, the men spent much time scraping off the goo. Still, they managed to chalk up a respectable fifty-four and a half miles the first day. This tenacity stayed with the men over the entire journey—and they would need it.

The corps reached the Continental Divide on the fourth day, just as a terrible sleet storm set in. Boos reported: "The snow was so thick that we could not see twenty feet in front of us and the air very cold and icy. Our ears and finger tips were numb, but there was no alternative. We had to go on and on we went." Several times over the course of the trip local citizens gave inaccurate descriptions of the road conditions ahead. Before the corps reached Bozeman, Montana, for example, poor information guided them onto a blind trail, which ended in a marshy field filled with mosquitoes.

Through constant rain, over steep, rock-strewn roads, the cyclists rode from Bozeman to Billings, Montana. One unforeseen hazard was the local populace, which, besides being less than trustworthy about the surrounding geography, was sometimes contemptuous of wheelmen, especially black ones. Near Billings three women in a wagon laughed derisively at the corps and refused to let it pass. Lieutenant Moss, unamused, seized a brief opportunity and charged the corps on by, so astonishing the women that they forgot to mind their spooked horses, which sped off into the rough.

Fort Custer, Montana, was the goal after Billings. As the men crossed the Crow Indian reservation, barren, lonely country confronted them, along with the ever-present sheets of rain. Riding became impossible. Moss wrote of this stretch: "About 8 o'clock the bark of a dog indicated that we were not the only human beings in those God-forsaken hills." At Fort Custer the men received a warm welcome, although the great mosquito swarms caused one soldier to comment it was probably insects and not Indians that had killed the man for whom the fort was named.

The corps was glad to leave the drenching rains of Montana, but the ninety-mile ride from Fort Custer to Sheridan, Wyoming, included very rough and hilly roads and seven crossings of the Little Bighorn River. They were fortunate enough to miss a violent hailstorm that had recently passed through the area, but not the eight-foot drifts it had left behind.

The corps reached Gillette, Wyoming, on June 29 at 2:00 P.M., after very little sleep and a twenty-mile uphill grind under a merciless sun. "Many of the men were so tired they fell asleep while eating," Boos wrote. Beyond Gillette the next station with water was Moorcroft, thirty miles away. Lieutenant Moss, told that the roads were very good, roused the tired men late in the afternoon for what he assumed would be an easy four-hour ride. At seven o'clock, however, great clouds gathered. The darkness made the corps slow down, and soon afterward a broken axle forced them to dismount and walk their bikes.

Moss turned the corps over to the

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acting first sergeant and struck out ahead with three men and provisions, intending to have supper ready at Moorcroft for the rest. At about 12:30 A.M. Moss's group met with three others from the main body who had lost their way. "I was so tired and sleepy," Moss wrote later, "that the horizon appeared like a clothesline just about to strike me above the eyes. Three or four times I threw my hand out at this imaginary clothesline—I was really sleeping on my feet." The corps finally reached Moorcroft at 6:00 A.M. and slept soundly, having been awake for forty-five hours.

Riding over prickly-pear cactus, the wheelmen made it to South Dakota, where they drank alkali water, the worst they had yet encountered. Later on they came across sandy roads, foreshadowing the most difficult terrain of the odyssey, the sand hills of Nebraska.

Only an hour or two after hitting the hot sand hills near Alliance, Nebraska, Lieutenant Moss was incapacitated by the effects of the alkali water. During the next four days the troops were under the command of the surgeon, J. M. Kennedy, while Moss traveled to the next stop by train. The ankle-deep sand of the wagon trail made even bumpy railroad ties look attractive, and they followed the line of the Union Pacific Railroad for the entire 170-mile sandhill stretch, riding under an intense sun in temperatures of one hundred degrees.

At the midpoint of the sand hills, on July 7, half the corps was sick and two men had developed terrible blisters on their feet from the searing sand. Boos was assigned the difficult job of determining which men were truly sick and which were acting the part to earn a rest. Remarkably, though, the ailing group covered this 170-mile oven in four and a half days, an average of 38 miles per day. Conditions improved by the time the men reached Lincoln, Nebraska. The sand hills were gone, and the end of the trip was in sight. The shimmering prospect of Missouri's clay roads lay ahead.

Despite more rain, and roads that turned out to be worse than expected, Missouri was easy after the heat, bad water, and sand of Nebraska. However, the citizens of Missouri were sometimes less than pleased with black soldiers on bicycles, wearing uniforms that many still associated with the Civil War–era Union Army, pedaling across their fields. Coming upon one farmhouse, Boos approached the owner to inquire about camping nearby. The farmer replied by telling them to "pile right offa this land," while his wife sarcastically offered the space below the pigsty.

Bicycles were cheap, quiet, and less visually conspicuous than horses. They also did not eat, raised little dust, and needed no caretakers.

Adding to the hostility of the local citizens, the corps experienced its first casualty at St. Joseph, Missouri. A private, claiming to be ill and unable to continue, was sent back to Fort Missoula. Of this incident Moss remarked (despite his own earlier incapacity): "I have every reason to believe this soldier was merely feigning illness thinking I would send him the rest of the way to St. Louis by rail. As he had given me trouble on several occasions, I thought it best for the public service to send him back to his station."

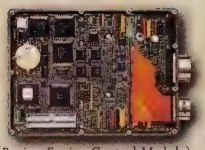
All the pain and discomfort the corps had endured began to disappear when the men crossed the Missouri River at St. Charles, where a small delegation of wheelmen from St. Louis heartily greeted them. The ecstatic corps rode into St. Louis at 6:00 P.M. on July 24 to cheers from large groups of wheelmen and citizens.

The St. Louis *Republic* ran a front-page story reading in part: "When Lt. Moss and his men dismounted amid the cheers of the waiting wheelmen, they did so with the knowledge that they had accomplished the greatest military bicycle feat ever proposed on this continent. In importance, the successful termination of the trip is almost beyond comprehension. It can mean no less than the ultimate adoption by the war department of bicycles as an adjunct to the fighting equipment of the army, and permanent establishment of bicycle corps in every post in the country." However, the story also noted that no officers from the Army were present to welcome them.

This absence proved to be significant. Lieutenant Moss had planned a return trip by bicycle to Fort Missoula, and even envisioned a future coast-to-coast experiment. But to Moss's dismay the corps was ordered to return to its station by rail, despite high praise from General Miles. While the 25th Infantry Bicycle Corps had shown that troops could travel by bicycle, the Army evidently decided that the difficulties involved were too great.

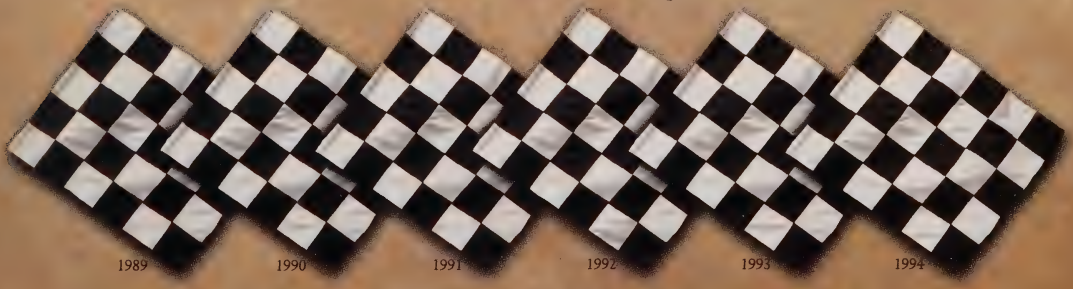
Lieutenant Moss never saw his cherished dream fulfilled. The corps was disbanded on April 10, 1898, and the Army experimented very little with bicycles after that. Poor roads, the vast size of the country, a large supply of horses, and a heavy bias toward railroads all worked against the bicycle as a method of troop movement. (In Europe, however, particularly France, conditions were opposite, and Moss's experiments encouraged the establishment of similar units.) Shortly after the turn of the century motorcycles and automobiles became widely available, dealing the final blow to military bicycling in the United States. ★

Gregory J. Daschle is a former resident of Missoula, Montana.



(Racing Engine Control Module)

In the last 6 victories at Indy, no matter who's controlled the car, we've controlled the engine.



Different cars have won at Indianapolis over the last 6 years. So have different teams, drivers, even different engines. But each year, it's been the same brand of engine control electronics. **Delco Electronics**

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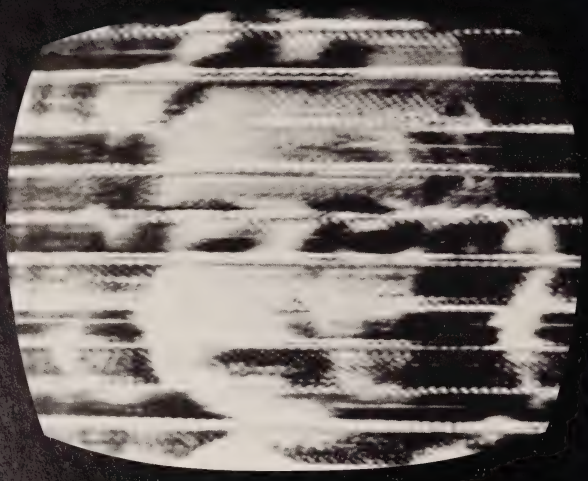
The Race to Video



Ampex's picture gets clearer: Left to right, a Shirley Temple movie tape with AM signal processing, late 1953; "The Bob Crosby Show," taped with FM signal processing, early 1954; a kinescope from mid-1954; and an FM recording from early 1956.

BY STEWART WOLPIN ■ Brig. Gen. David Sarnoff—chairman of the board of RCA, founder of NBC, radio pioneer, adviser to Presidents, and the most powerful and visible man in the business of broadcasting—made three wishes.

It was September 27, 1951, forty-five years since Sarnoff, at fifteen, had begged Guglielmo Marconi for a job at the wireless inventor's American Marconi offices in New York City. To mark this anniversary, RCA's R&D facility in Princeton, New Jersey, was being rechristened the David Sarnoff Research Center. In his luncheon speech the General ordered three gifts to be ready for his fiftieth anniversary, five years later: an electronic air conditioner, an electronic amplifier of light, and something he called the "videograph," a "television picture recorder that would record the video signals of television on an inexpensive tape." Sarnoff envisioned it as "a new instrument that could reproduce TV programs from tape at any time, in the home or elsewhere."

Sarnoff expected these gifts to be produced in his namesake lab, of course. "But it is in the American spirit of competition that I call attention, publicly, to the need for these inventions," he added. Over the next five years the General would often repeat his wish, never really believing that anyone but RCA could fulfill it. In fact, though, that third challenge sparked one of America's great technology races.

In the early 1950s no one imagined anything like Blockbuster Video. Television executives wanted a videotape system for much

AMPEX CORPORATION

THE CHALLENGE came from one of broadcasting's most revered figures: Build a working videotape recorder in five years. The competition was intense, and the victor turned out to be a small, virtually unknown firm. The results changed entertainment forever.

less ambitious reasons. Because of time-zone differences, programs had to be recorded while being broadcast live in the East for rebroadcast three hours later on the West Coast. Broadcasters had only one way to accomplish this time shift, a film process known as kinescope.

"Kines" (pronounced *kinnies*), as they were known, were made by filming the picture off a high-resolution television set using a special synchronized 35-mm or 16-mm movie camera. The film then had to be processed as quickly as possible and rushed back to the studio for rebroadcast. Kinescopes, however, required a lot of time and labor. The picture quality was often poor because of the problems of synchronizing thirty-image-per-second television broadcasts with twenty-four-image-per-second movie equipment. On top of all this, kines were expensive; filming a half-hour show could cost as much as $4,000. By 1954 the American television networks were using more film than Hollywood. The broadcasting industry was desperate for a solution.

In principle the problem was not hard. If sound and light could be turned into electrical signals for broadcast, they could presumably be stored, just like any electric current, on a magnetic material. The first such medium, for sound recording, was magnetized steel wire. It had been demonstrated in 1900 by the Danish inventor Valdemar Poulsen and refined in the 1930s by Marvin Camras of the Armour Research Foundation (now the Illinois Institute of Technology), a research consortium of some 125 companies that could license any technology Armour came up with. Unfortunately, it

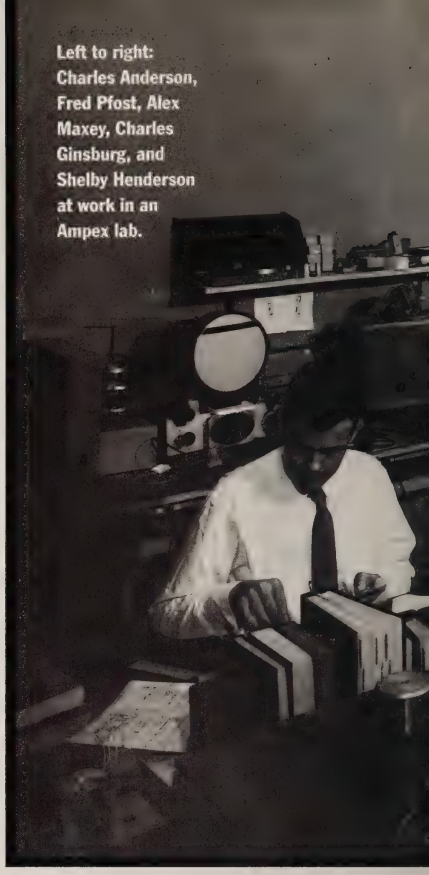
was wholly inadequate for storing video. A typical visual image contains much more information than a sound recording, and thus television broadcasting—and recording—requires an enormous range of frequencies. The leap from sound recording would be like the difference between a paper airplane and a moon rocket. But in the shadow of Edison, Einstein, and the atomic bomb, Sarnoff shared the popular notion of the time that science could accomplish anything.

The more capacious magnetic medium that was needed would probably be some sort of metal ribbon or tape. But no one had been able to perfect a magnetic recording tape—at least not in what was then the free world. In 1935, however, BASF (a subsidiary of the German chemical giant I. G. Farben) had developed a cellulose acetate–based tape coated with iron oxide particles for use in an audio recording device called the Magnetophon. The Magnetophon was manufactured by AEG, Germany's General Electric. World War II kept this development hidden from American and British engineers, but the fledgling television industry discovered magnetic tape at the end of the war thanks to an Army Signal Corps major named Jack Mullin and a determined singing star who wanted to be able to tape his weekly radio show—Bing Crosby (see sidebar on page 58).

Mullin had graduated from the University of Santa Clara with a B.S. in electrical engineering in 1937 and worked for Pacific Telephone & Telegraph in San Francisco until the United States entered the war. Mullin served with the Signal Corps in England, then was sent to the Continent as the war in Europe ended. While searching a Radio Frankfurt studio, Mullin discovered a Magnetophon studio model R22A. The machine used BASF's acetate-based recording tape coated with red iron oxide particles and yielded far better sound fidelity than any other recording medium. Mullin took two Magnetophons apart and mailed the pieces, along with fifty reels of tape, to San Francisco in thirty-five small packets. When he got home, Mullin reassembled and modified the Magnetophons and on May 16, 1946, unveiled audio tape recording to his stunned peers at the Institute of Radio Engineers convention in San Francisco.

Crosby signed Mullin up as chief engineer of Bing Crosby Enterprises (BCE), but he wasn't the only one interested in the Magnetophon. A two-hundred-employee company in Redwood City, California, called Ampex, founded in 1944 to make motors for airborne radar sets, was trying to shift from defense to civilian industry. Working with Mullin as a consultant, Ampex produced the first American commercial audiotape recorder, the Model 200, in April 1948. By August the Ampex machines, using a new kind of tape developed by 3M, had replaced Mullin's rebuilt Magnetophons on the Crosby show.

The introduction of magnetic tape recording sparked a revolution in the broadcasting industry. When the excitement reached Marvin Camras, who had perfected wire recording almost a decade earlier, he began his own research into video recording using 3M's new magnetic tape. To record the much wider video signal, Camras would have to speed up the tape from 15 inches per second (ips), the standard for sound recording, to 300 or 400 ips. A length of tape that could hold half an hour's worth of sound would hold considerably less than a minute of video, after allowing for the amount wasted getting the motor up to the ridiculously high speed. At that rate a reel of quarter-inch tape would have to be more than two feet across to hold fifteen minutes of video.



Left to right: Charles Anderson, Fred Pfost, Alex Maxey, Charles Ginsburg, and Shelby Henderson at work in an Ampex lab.

Camras decided to bring the mountain to Muhammad. Instead of pulling tape at lightning speed past a fixed recording head, he decided to move the recording head past the tape. Camras mounted three heads on the face of a rotating drum and attached them to a Hoover vacuum-cleaner motor that turned at 20,000 revolutions per minute (rpm). This allowed him to use tape two inches wide, which reduced the required speed by a factor of ten. He knew he was onto something, but other projects drew him away, and he put the rotating-drum idea aside.

Like Camras, Jack Mullin realized the potential of magnetic audiotape for video recording, though it did not occur to him to use a moving head. In June 1948 he and Wayne Johnson, a BCE radio technician and engineer,

Sarnoff often repeated his wish for a video recorde

AMPEX CORPORATION

started experimenting on a modified Ampex Model 200 sound recorder. They proved the feasibility of pulling quarter-inch tape past a fixed head at high speed, and on November 14, 1950, Mullin applied for a patent for "video recording methods."

In June 1951 Crosby rewarded Mullin and Johnson with a brand-new laboratory at BCE's headquarters in Hollywood. Sarnoff's challenge three months later spurred Mullin and Johnson on: The General's speech, Mullin later recalled, "made us enthusiastic and encouraged us to get busy and work as fast as possible."

They may have worked too fast. Frank Healey, the prototypical publicity man who ran BCE's new electronics division, wanted to show RCA and the world that his boss had the upper video hand. The only problem was that Mullin and Johnson weren't ready yet. They were in the midst of developing a multiplexing technique that would break the signal into twelve tracks: ten for video, one for audio, and one for the synchronization of horizontal and vertical.

On November 11, 1951, a month and a half after Sarnoff's speech, Healey invited the press to BCE's laboratory for a demonstration. Mullin and Johnson went back to the modified Model 200, using standard quarter-inch audiotape running at 360 ips to record a single track. The tape transport was supplemented with racks of electronics filled with vacuum tubes, all of which yielded a mere forty lines of resolution, one-eighth of the prevailing broadcast standard.

"We had 'recorded,' if it could be called that, some TV pictures of airplanes landing and taking off," Mullin recalls. "When we gave the demonstration, Frank would stand by the monitor and say, 'Now watch this plane come in for a landing' or 'There goes a guy on takeoff.' It is doubtful the viewer would have known what he was seeing without this running commentary."

On the basis of this "demonstration," Healey was bolder than Sarnoff and predicted that BCE would have commercial models in general use within a year. Regardless of Healey's hucksterism and the poor quality, it was the first public demonstration of television recorded on magnetic tape. Healey had achieved his publicity objective, one-upping Sarnoff and RCA.

RCA executives weren't exactly sitting on their oscilloscopes, however. Harry F. Olson, chief of RCA's video recording project, had already assembled a team in Princeton, at RCA's Acoustical and Electromechanical Research and Systems Research Division. Its goal was to build what Sarnoff dubbed a "Hear-See" machine, which could record both color and black-and-white. Taking a cue from Mullin, the RCA team built four enormous electronic closets, each more than seven feet tall. Using reels of half-inch tape a foot and a half in diameter moving at 360 ips past a fixed head, they could produce four minutes of single-channel black-and-white video. It was a long way from the commercial product Sarnoff had predicted.

Meanwhile, a third company was entering the field. Ampex engineers visited Camras at the Armour Foundation in early 1951 and saw a casual demonstration of his rotating-head video recorder. They recognized its value.

Camras's rotating head could give

never believing that anyone but RCA could fulfill it.

Recording video would be much harder than sound—th

Ampex a technological jump on RCA and BCE, and the low-key company could easily keep away from the public spotlight that both its competitors sought out. In October 1951, shortly after Sarnoff's speech, Ampex's founder and president, Alexander M. Poniatoff, allocated a modest $14,500 for initial development and started looking for a project leader naive enough not to know the impossibility of the job ahead.

The leader came on the scene by chance. An Ampex employee living in San Mateo had a neighbor who worked in the transmitter house at KQW radio in San Jose (now KCBS in San Francisco). The neighbor's name was Charles Pauson Ginsburg, and he was dying to get into something related to television. At the employee's suggestion Poniatoff gave Ginsburg a call, and he liked what he found.

Ginsburg, born on July 27, 1920, had started his electrical-engineering life like most boys of his day: building crystal radio sets and nearly electrocuting himself. He attended several different colleges as a young man, with several different majors, but renewed his interest in electrical engineering after taking a part-time job installing private telephone exchanges. He finally graduated from San Jose State in 1948, with a major in mathematics and engineering. After several years on the night shift at KQW, Ginsburg was offered the position at Ampex, and he began work in January 1952 in an office right next to Poniatoff's.

Poniatoff was attracted to Ginsburg as much for his enthusiasm as for his technical knowledge. Ginsburg was more open and happy-go-lucky than most of his engineering brethren. "When you talked to him, you knew he was interested," one colleague remembered. "He was tenacious but easy to get along with. He was able to take suggestions." Everyone loved to tell him jokes. No matter how bad they were, Ginsburg would start to giggle, then burst into hysterical laughter. His good nature may have stemmed from the fact that he had survived diabetes; he was one of the world's earliest insulin takers and felt lucky to be alive.

In early April 1952 a precocious nineteen-year-old named Ray Dolby stopped Ginsburg in the hallway and interrogated him about the supposedly secret video project. Dolby had been working part-time for Poniatoff for about three years. In the spring of 1949 Poniatoff had needed a film projectionist and called the audiovisual club at Sequoia Union High School, in Redwood City. The club's faculty adviser suggested Dolby, and the sixteen-year-old prodigy and the sixty-year-old patrician quickly hit it off.

Whenever Dolby's school schedule and Ampex's finances permitted, he worked in the company's engineering department. During his senior year, in 1951, Dolby acquired national-security clearance for his work on the construction and testing of a multitrack FM recorder for the Naval Ordnance Laboratory. He earned his first patent that summer by perfecting an electronic synchronization technique for Ampex's audio recorders.

Just as Dolby got on famously with Poniatoff, he also got on with Ginsburg, and the two became fast friends. They started working together on a variety of projects, including what they called the TVR (television recorder). By August 1952 Dolby was ready to drop out of San Jose State and join Ginsburg and the TVR project full-time. He examined the last machine Ginsburg had devised and was not impressed, so he decided to start from scratch. Scavenging the laboratory for parts, he assembled a Camras-style three-headed drum

Pfost, Henderson, Dolby, Maxey, Anderson, and (leaning) Ginsburg surround Ampex's VR-1000, 1956.

LEFT: AMPEX CORPORATION; RIGHT: VIDEOTAPE—DENNIS NOLAN

ifference between a paper airplane and a moon rocket.

on a 3,600-rpm motor. Using electronics from an Ampex instrument recorder and two-inch tape, he managed to crudely but successfully reproduce some test signals.

The first problem, however, was that the picture wouldn't stand still. Dolby suggested using two pairs of synchronized heads instead of three single heads, but the so-called Quad assembly sounded like a buzz saw, tore up tape, and threw oxide particles all over the lab. An Ampex machinist, Shelby Henderson, milled the first "female guide" —twin rotating needlelike posts that kept the tape exactly located—to solve the tracking problem. Ginsburg and Dolby were ready for their first show-and-tell.

On November 19, 1952, they played for Poniatoff and a few other executives a fuzzy, indistinct black-and-white video of a cowboy show. When the silent short ended, Poniatoff exclaimed, "Wonderful! Is that the horse or the cowboy?"

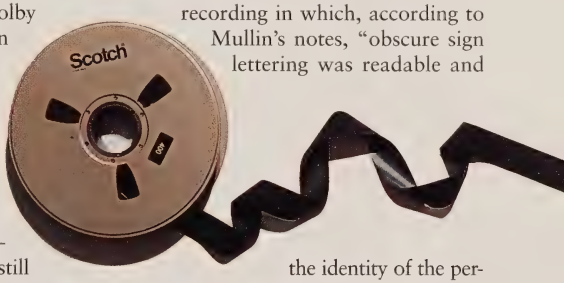
The biggest of the many technical problems was playback. Ginsburg and Dolby could record better than they could recover what they had recorded. After some consideration Dolby suggested using a pulse modulation scheme that would widen the range of the signals at playback.

A couple of weeks after the cowboy test, Ginsburg and Dolby taped a Krazy Kat cartoon in which Krazy pulled up to a roadside stand with a sign that read LEMONADE 5¢. At playback, using pulse modulation, the sign was legible. The team had leaped light-years in just a fortnight. The playback was still plagued, however, by what Ginsburg called "Venetian blinds," periodic horizontal streaks caused by the crossover from one rotating head to the next.

Dolby was lying in bed at his rooming house one Sunday morning in December thinking about that problem when suddenly it occurred to him that "the basic conception and geometry were wrong." He sketched out a new four-head scheme, then drove the fifteen miles to Ginsburg's house. The two tried to pick apart the idea but could find no flaws. Less than a month later it tested successfully. By March 1953 the new machine, with its head assembly spinning at 14,400 rpm, could record twice the range of frequencies previously achieved.

The same spring, with his student deferment gone, Dolby was drafted. He left Ginsburg his notes and went off to St. Louis, assigned to teach electronics in an Army school. In June he received a letter from Ginsburg: Ampex had decided to suspend development of the renamed "video tape recorder" (VTR) to work on a stereophonic sound system for wide-screen movies, to be called Todd A-O, for the producer Mike Todd.

While the Ampex and RCA teams were still experimenting, Mullin and Johnson at BCE progressed far beyond their first, crude demonstrations in 1951. In August 1952 they showed off their twelve-track multiplexing system, which moved at 120 ips, at two technical conventions. On October 3, in a demonstration for the project's five-man staff, Mullin and Johnson played back a black-and-white recording in which, according to Mullin's notes, "obscure sign lettering was readable and the identity of the personalities in long shots was possible."



Many problems remained, including flicker, lateral jiggle, and ghosts. Still, the system was good enough to merit another press conference. On Tuesday, December 30, the team showed reporters a jittery recording of the previous Sunday night's Jack Benny program. According to *The New York Times*, "those who a little more than a year ago saw the company's initial attempt to tape-record television off the air expressed amazement over the quality of the pictures obtainable." Healey, the BCE publicist, promised to demonstrate a videotape "equal in quality to a live telecast picture" by May 1953, and again predicted the commercial production of recording machines within a year.

Despite the lack of actual working VTRs, there was a lot of industry talk about the future of videotaping. In a speech on March 25, 1953, Sarnoff predicted that videotape would make the use of film obsolete for television. A month later Mullin promised commercial television tape from BCE by 1954. He reported that BCE's group had eliminated flicker and lateral jiggle, reduced the screenlike pattern, and

made encouraging progress on the reduction of streaking and ghosts. Two days later Sarnoff predicted a working system within two years.

The publicity Sarnoff and BCE were generating sparked video research all over the world. In the United States, DuMont, General Electric, Alan Shoup Labs in Chicago, Bell Television, and the television division of the Federal Communications Commission all went to work on some sort of fixed-head system. In 1952 the British Broadcasting Company embarked on a multiplex VTR project dubbed VERA, for Vision Electronic Recording Apparatus. In July 1953 Eduard Schüller of Hamburg, Germany, applied for a patent on single- and dual-head helical-scan VTRs there. All these efforts eventually faded away.

Ampex's rotary-head developments were still hush-hush. Although Mullin continued to work with Ampex as a consultant on some audio projects, Ginsburg would play dumb whenever Mullin asked about his video experiments. However, RCA was kept apprised of what BCE was up to. Healey, always eager to blow Crosby's horn, invited Sarnoff and his staff out to Los Angeles for a demonstration in mid-1953. "They all drove up in three black limos, one guy in each car," Mullin recalled. Sarnoff sat impassively through the demo, which Mullin later described as "looking like a good half-tone." Afterward the General was quiet but courteous, said "Thank you," and left without comment.

Sarnoff must have been burned by Mullin's relative success. Here was a small group of newcomers running rings around his enormous research complex. But to RCA's engineers the VTR research was simply a job. Mullin, Johnson, Ginsburg, and Dolby were passionate visionaries as well as engineers.

A differing technical approach was also partly to blame for RCA's apparent lag. To allow for color recording, Sarnoff's team was still pursuing the single-channel method, which Mullin had abandoned. "We didn't have any choice," an RCA team member explained. "We had the order from God himself that the system we put on the air would have to precisely satisfy the NTSC [National Television Systems Committee, an FCC subgroup] standards for color. We could see no way that one of these other systems ever had a chance of meeting those stringent NTSC standards"—since RCA and Sarnoff had been the prime contributors to writing them, and they naturally favored RCA technology. In the long run Sarnoff was right, but color broadcasting would not become commonplace until the late 1950s. In the short run, with black-and-white still dominant, his decision subjected RCA to much criticism and embarrassment.

RCA's videotape recording system, called Simplex, had its first public demonstration on December 1 and 2, 1953, at the Sarnoff labs in Princeton. Actually two systems were demonstrated, one for black-and-white and another for color, using recordings of several scenes starring the actress Margaret Hayes. The color system used half-inch tape to record five tracks—one each for red, blue, green, synchronization, and audio. The black-and-white system used quarter-inch tape with two tracks, one for picture and one for sound. Both systems ran at 360 ips. It took more than a mile of color tape to hold a four-minute, 240-line non-NTSC recording, which needed about fifteen seconds to get up to speed.

The press, perhaps cowed by Sarnoff, was respectfully impressed. A trade paper called *TV Digest* said, "The black & white was better than most kines and as good as some film." But the General knew better. There were rumors that he had moved the front seats ten rows back to hide the poor picture quality.

Healey was miffed that he and Mullin hadn't been invited to RCA's December demos, and he called RCA to request reciprocation. Healey, Mullin, and Johnson traveled to Princeton in June 1954 to see the RCA system. "It was darn good," Mullin recalled. "It

How Bing

BY J. M. FENSTER

The country's most popular entertainer used German wartime technology to bring tape recording to network radio

In 1933, as the Nazis took control of Germany and began to prepare for conquest, one of their first priorities was research into radio communication. Two years later German industry produced a new tool for the trade of listening: the Magnetophon magnetic tape recorder. The Magnetophon was the first truly practical recorder that used tape, and it emerged in the aftermath of World War II to set the modern course of magnetic recording. In America Bing Crosby staked his career in broadcasting to start a revolution for Magnetophon technology.

At the beginning of World War II, when the Germans were relying on tape recording, the Allies turned to magnetic recorders running wire or steel bands. All three were roughly equivalent in their common uses: speeding coded transmissions, retaining flight and battle information, and monitoring enemy communications. The tape recorder, however, offered far greater potential for improvement.

As the German army advanced and occupied more territory—in various time zones—Nazi leaders balked at having to repeat their radio speeches over and over again. Two engineers at the German Radio Network, W. Weber and H. J. von Braunmühl, were assigned to improve the Magnetophon so that it could fool radio listeners into thinking that they were hearing live broadcasts. Working in Berlin in

CROSBY BROUGHT YOU AUDIOTAPE

the summer of 1940, Weber and Braunmühl learned that the addition of a high-frequency current in the recording process would clear out extraneous hisses. At around the same time, I. G. Farben, the chemical concern, developed a plastic tape that improved the consistency of the Magnetophon's sound reproduction.

The new Magnetophon was so effective that American intelligence officers didn't even know of its existence until they noticed that certain German leaders seemed to be on the air around the clock delivering live speeches. John Mullin, an Army Signal Corps technical expert, reported hearing Berlin Philharmonic programs in the middle of the night with sound far better than from records. From afar the Americans realized that the Nazis had perfected sound recording.

When the Allies took the offensive in France in 1944, advance troops were given orders to retrieve a Magnetophon at the earliest opportunity. All that they found, time after time, was that German radio operators were obeying orders to destroy equipment before leaving it. Finally, in April 1945, the Americans captured a Magnetophon in Frankfurt-am-Main. Technicians, including Mullin, arrived to examine it, but by then the Signal Corps was overwhelmed with captured matériel.

As the war came to an end, the GI readers of *Yank* were asked to vote for the person who had done the most to boost their morale overseas. The winner was Bing Crosby. Crosby was the number-one movie star in America and sold more records than anyone else, by far. He was also the most popular singer on the radio, yet when he said he wanted to prerecord his weekly show, the "warfare was practically frontpage news," as he wrote in his memoirs. All prime-time radio shows were broadcast live before 1946. Recorded shows were outlawed on the basis that they would undermine the function of the networks and sound cheesy anyway.

ABC Radio, the weakling among networks, took Crosby in, gladly, and he was allowed to record his show using the reigning technology of the day, wax disks. This victory gave him creative control, but most of all it meant that he wouldn't have to be in town and at the studio on thirty-nine straight Thursdays each year.

Bob Hope was the guest star on Crosby's first recorded program, October 16, 1946, and on later shows. Whenever he ad-libbed something racy during the show or read a joke that fizzled, he would lean back and call over to the sound engineer, "Lift the needle on that one, will you, boy!" Editing a wax disk was a laborious process, but it allowed engineers to take what Crosby called "the flab" out of a show, leaving the best thirty minutes for broadcast.

At first the experiment worked; ratings were high. As the season progressed, though, the show faltered amid complaints that the music sounded tinny and Crosby's voice "fuzzy." The whole process appeared to be more trouble than it was worth, and Crosby came under terrific pressure to give it up and revert to live broadcasts. But he delayed a decision and asked his producers to investigate magnetic recording. Magnetic recording in its wire form was a rising star of the postwar market, but it seemed unlikely to offer anything good enough for a radio show until the producers met Mullin, who had sent two surplus Magnetophons home from the war. He staged a demonstration of his own improved version, developed in conjunction with a flagging company called Ampex.

The season premiere of Bing Crosby's show, October 1, 1947, was the broadcast premiere—in America—of magnetic tape recording. It sounded so much like a live broadcast that other radio stars immediately demanded to prerecord their shows; the old network ban subsequently collapsed. Radio stations and record producers, rushing to buy Ampex tape recorders, were directed to deal with the distributor, Bing Crosby Enterprises. Ampex used its Crosby windfall to develop other commercial recorders, becoming a leader in the industry, and Mullin took the job of chief engineer at Bing Crosby Enterprises.

Jack Mullin, Frank Healey, and Wayne Johnson show Der Bingle their recording apparatus, around 1952.

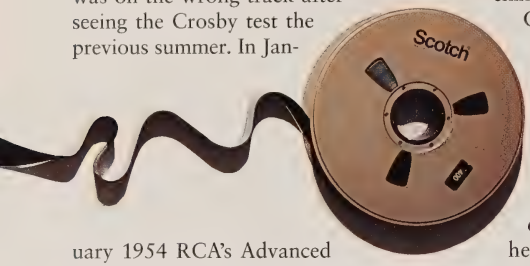
Bing Crosby was the only entertainer powerful enough to advance the development of magnetic tape so quickly. He also happened to be the only one clever enough to want to and stubborn enough to need to.

J. M. Fenster writes often for Invention & Technology.

COLLECTION OF JOHN T. MULLIN

made us realize that we were on the wrong track." Mullin and Johnson's system was much more complicated than RCA's, and while the picture quality was comparable, it seemed to offer less room for improvement. The two went back to Hollywood and abandoned multiplexing for the five-track RCA color method. But they found switching to someone else's method discouraging. "We didn't have the enthusiasm," Mullin admitted. "We had lost our sense of urgency."

Ironically, Sarnoff had thought RCA was on the wrong track after seeing the Crosby test the previous summer. In January 1954 RCA's Advanced Development Laboratory in Camden, New Jersey, started a parallel effort to develop a fifteen-track multiplex color machine, but they ran into the same technical problems that had caused Mullin and Johnson to abandon the system. Eventually Harry Olson's Simplex team would be reduced to working on a cumbersome black-and-white home machine, which was unveiled rather anticlimactically to a disappointed Sarnoff for his fiftieth anniversary in September 1956. Essentially, in 1953 and 1954 RCA and BCE had traded dead ends.



Back in Redwood City, Ginsburg had kept up a lively correspondence with Private Dolby. Ginsburg couldn't stand his superior on the Todd A-O project and wanted out. Along with Charlie Anderson, who had joined Ampex in the spring of 1954, he continued to tinker secretly with the VTR.

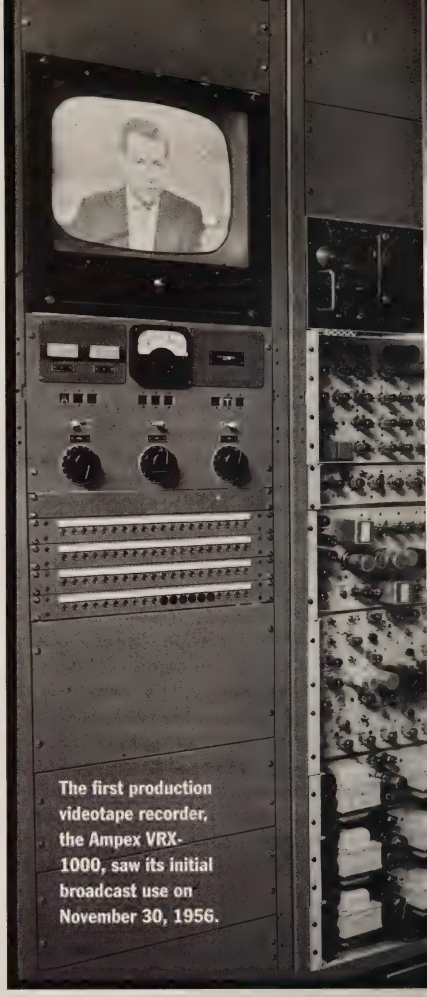
It was a difficult time for Ginsburg, who was officially forbidden to work in video but kept reading about RCA's and Mullin's advances. In August 1954 Ginsburg showed a management committee a revamped Quad machine, which incorporated improvements that he and Anderson had surreptitiously made. The executives were sold, and they restarted the VTR project as of September 1.

Once again Ginsburg assembled a VTR team. First of all it included Anderson and Shelby Henderson, the machinist. From the Todd A-O team Ginsburg recruited Fred Pfost, a young expert on recording heads. In October these four and Dolby were joined by the assembly designer Alex Maxey, a twenty-eight-year-old high school dropout and mechanical prodigy who had heard about the project and wangled an interview with Ginsburg.

Dolby returned from the Army in January 1955 to discover two major developments. The first was a new scanning technique. Maxey had turned the angle of the head drum ninety degrees to produce a system called transverse scanning, in which the video signal was written in zigzag lines nearly perpendicular to the direction of the tape. This replaced arcuate scanning, in which the signal was written in lengthwise arcs. The tape speed had also been reduced from 30 to 17½ ips.

The second new development was the creation of a workable frequency modulation (FM) system to replace the previous AM and pulse modulation. Dolby and every other engineer working on magnetic recording had thought that an FM signal would take up too much space on the tape, but Anderson had managed, in essence, to shrink the FM wave.

With that solved, it became a matter of tinkering and time. On January 13, 1955, the team recorded and played back the widest video signal yet. In February new problems cropped up, but they were mechanical, not electronic. Pfost again reinvented the video recording heads, and Maxey fashioned new designs for the tape guide, transport, and rotary drum. Further experimentation and debugging followed, including the addition of an audio track.



The first production videotape recorder, the Ampex VRX-1000, saw its initial broadcast use on November 30, 1956.

On March 2 the Mark I Quad machine was demonstrated for Ampex's board of directors. The recording consisted of a just-broadcast news report by Eric Sevareid about a ship in distress. As the playback began, Pfost,

After the demonstration ended, Poniatoff was politely e

sotto voce, told Ginsburg to turn up the volume. "With the sound turned up high, the flying spray, the roaring storm, and Sevareid's booming voice, the board didn't seem to notice the noise in the picture," Pfost noted. The picture might not be up to broadcast standards yet, but the team felt the major problems had been solved. They decided to shoot for an unveiling in April 1956 at the National Association of Radio and Television Broadcasters (NARTB) convention in Chicago.

One of the most vexing and persistent remaining challenges was head wear. The material being used in recording heads would last barely ten hours under the strain of video recording. Pfost solved the problem with an aluminum-iron alloy called alfenol, made by the Hamilton Watch Company, which yielded a head that could last thousands of hours. On July 7, with the alfenol head in place, Dolby noted that "overall picture quality was judged the best yet seen."

By this time Dolby was spending fifteen hours a week at Stanford University, having finally resumed his aborted college career, and three days a week at Ampex. This part-time status created a logistical problem: what title to give to an engineer who had no degree but held or co-held several of the company's most important patents. Ginsburg arranged for Dolby to be called a consultant. (In June 1957, when Dolby earned his degree, he was promoted to senior engineer.)

Not all the team's nontechnical problems were as easy to solve. Inevitably there were personality clashes. "We were a bunch of normal people," noted Anderson. "There were people on the team whom I liked and grew close to; there were others I respected but did not draw close to." The egos of Dolby, the boy genius, and Anderson, an older and more established engineer, often collided. Pfost, who felt he wasn't getting the credit he deserved, fought constantly over technical details with the normally jocular Maxey.

Ginsburg, more administrator and mathematician than engineer, mediated technical disputes and refereed the constant bickering. He was the one man everyone respected and liked, the glue that held the factions together. "Charlie was a great leader because he left us alone," remembered Pfost. "It was a family situation, and Charlie was the father."

Through 1955, as Ampex went quietly on its way, RCA and BCE engaged in technical brinkmanship with dueling dog-and-pony shows for the press that merely illustrated how far they still had to go. At the dedication of a new 3M research facility in St. Paul, Minnesota, in May, RCA made its first transcontinental broadcast from a color videotape. The imperfect recording contained remarks from Sarnoff, a brief explanation of the system by Olson, and clips of entertainers. Not to be outdone, Mullin demonstrated BCE's color system in November. According to *Broadcast* magazine, the recordings "did not match the present live product seen on the color set screen." Olson and Mullin began to realize that their systems were as good as they were go-

usiastic: "Wonderful! Is that the horse or the cowboy?"

ing to get, which wasn't very. High-speed, fixed-head video recording simply wasn't practical.

Meanwhile, word of Ampex's work started to leak out. Late in 1955 the company tried to downplay it, saying that a practical device was three years away. In fact, three months was more like it. In early February 1956 the team demonstrated its transverse scanning, FM-carrier prototype for thirty Ampex employees, most of whom were seeing video recording for the first time. As soon as the short black-and-white recording ended, the group rose en masse and started applauding and shouting. According to Ginsburg, "the two engineers who had done more fighting between themselves [Pfost and Maxey] shook hands and slapped each other on the back with tears streaming down their faces."

Several visitors were also shown the system, including William Lodge, CBS's engineering vice president, and Mullin, who watched with a combination of shock, envy, and disappointment: "I said, 'It's all over for us.' It was a beautiful picture, better than ours."

The president of Ampex, George Long, told stockholders in a letter that "Ampex has constructed a laboratory version of what is believed to be a practical system for the recording and reproduction of TV pictures on magnetic tape" but hastened to add that "the conversion of this laboratory prototype into a commercially acceptable unit will still require a considerable amount of additional time and effort." Privately, however, Ampex firmed up plans with Lodge to launch the machine at the CBS affiliates' meeting at the NARTB convention, less than two months away.

Long might not have believed it when he wrote it, but he was right: The Quad still needed a great deal of work. For the next six weeks Ginsburg's expanded group virtually lived in the laboratory. "I may have slept in the lab thirty or forty times," Pfost recalled. Ginsburg even discarded his usual business suit for a work shirt and jeans to pitch in on long nights and weekends. Pfost put in an average of a hundred hours a week experimenting and reconstructing heads. "There were many heroes during this period, but leading them all was Pfost," Ginsburg later said.

It was decided that two simultaneous official announcements would be made: one at the CBS affiliates' meeting on Saturday, April 14, and the other at Ampex's Redwood City offices. The team had been working on a unit called the Mark III, which consisted primarily of a wooden cabinet and two partially filled electronics racks. Mark III would be used for the Redwood City announcement. For the one in Chicago, the team decided to build a more presentable cabinet, designed primarily by Anderson, for what would be an $80,000 machine. The resulting sleek console was dubbed the Mark IV. "It was the most elegant video recorder that Ampex would produce for some time," Dolby recalled.

The Mark IV was broken down and shipped in pieces to Chicago. By Thursday, April 12, it had been reassembled and was producing its best pictures yet. On Friday the thirteenth, the day before the big Chicago demonstration, a test was run for Lodge and his engineering assistant, who complained about the high noise level. The team tweaked, with limited success, and realized that it needed better tape.

Pfost desperately called 3M's chief physicist, Wilfred Wetzel. Wetzel and his team spent that Friday night and early Saturday morning coating and testing sample after sample. Wetzel left the laboratory empty-handed early Saturday morning to make a flight to Chicago. Back in the 3M laboratory, technicians had a breakthrough, and at 6:00 A.M. they finished coating two five-minute reels. An engineer frantically drove the package to the airport, dashed onto the tarmac, and persuaded a ground-crew member to signal the pilot, telling him that Dr. Wetzel had to take an important package of medicine with him. The package was hoisted up to the plane's cockpit at the end of a long pole and passed back to an embarrassed Wetzel.

The new tape solved the last remaining problem. Everything was as ready as it was going to be.

More than two hundred managers of CBS affiliate stations from around the country were jammed into the Normandy Room of the Chicago Hilton on Saturday afternoon, April 14, 1956. Lodge was at the podium to give his annual presentation, and black-and-white television monitors lined the walls to make his speech visible to everyone in the crowded room. When Lodge finished, he said, "Now let's see what Ampex has for us." There was a brief delay, and just as the delegates began talking among themselves, the image of Lodge repeating his speech appeared on the monitors. But when the delegates looked at the lectern, Lodge was just standing there. The puzzled delegates once again stared at the monitors. Off to the side some curtains parted. Behind them were three engineers manipulating a gleaming machine the size of a desk.

Although there had been scattered press reports concerning videotape developments, these were usually small articles buried in industry magazines and gave no indication that any system was close to being ready for commercialization. But the station managers slowly realized that they were looking, for the first time, at perfected commercial videotape recording.

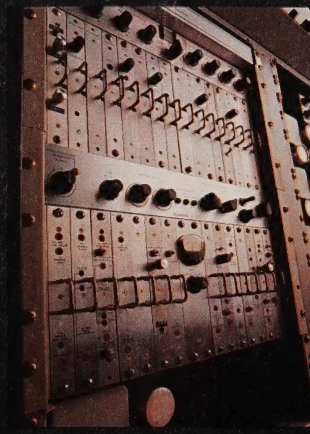
Pandemonium engulfed the room. Some in the audience just applauded, some stood on their chairs to get a better look, but most rushed toward the curtained area to examine the new electronic marvel. The exhausted Ginsburg, Anderson, and Pfost were swarmed by backslapping admirers. In four days Ampex took $5 million worth of orders for the new machines.

The video age had dawned. ★

Stewart Wolpin writes on consumer electronics for Video, Rolling Stone, *and many other magazines.*

OPPOSITE: COURTESY OF PAVEK MUSEUM OF BROADCASTING. PHOTOGRAPH BY DENNIS NOLAN.

Ampex's VR-1100, introduced in 1962, was the first transistorized video recorder. It was considerably more compact than the company's original model but still extremely cumbersome by today's standards. Above, a close-up of the recording-head assembly; below, the complex array of controls that users had to master.



BY LAMONT WOOD

The Man Who Invented the PC

"When I tell them I invented the personal computer, people look at me like I just stepped off a flying saucer," says Jack Frassanito, an industrial designer in Houston, Texas. He did invent it, though. His name is on a patent, issued July 25, 1972, for a machine that is the direct lineal ancestor of the PC as we know it.

Proto-PC: The Datapoint 2200 "smart" computer terminal.

Forget Apple and IBM. For that matter, forget Silicon Valley. The first personal computer—a self-contained unit with its own processor, display, keyboard, internal memory, and mass storage of data—was born in San Antonio, Texas.

The story begins in July 1968, when two Texans, Phil Ray and Gus Roche, founded a firm called Computer Terminal Corporation (CTC). As the name implies, they did not start out making computers; instead they made terminals to use with other manufacturers' computers. Their first product was an electronic replacement for mechanical teletypes.

In 1969 they decided to market a "smart" device that could mimic the terminal of any major computer vendor. Such an adaptable machine would have to have its own processor instead of simply passing along signals from a central unit. The company hired Frassanito to help develop the design. Since it would be used by office workers rather than engineers, CTC wanted to make it less intimidating by disguising the fact that it was a computer terminal.

"It was to have the footprint, size, and shape of an IBM Selectric typewriter," recalls Vic Poor, then CTC's technical director. The screen was only twelve lines high—the same size as the standard IBM punch card, since CTC also hoped to sell the new computer as a convenient electronic replacement for the mechanical card-punch machines then in use.

Poor laid out the terminal's workings on printed circuit boards. Fitting everything into such a small space led to crowding and heat problems, and Poor thought about reducing the circuitry onto a microchip. Such chips had been used for several years to perform specific logic functions, but never before had all the circuits for a central processing unit been put on a single one. Intel and Texas Instruments (TI) agreed to try, but neither completed its chip before CTC unveiled the terminal in June 1970.

It was called the Datapoint 2200, and it had up to 8,000 bytes of internal storage, with another 300,000 on two cassette tapes. It was some 4,000 times slower than the 486-class PCs available today. The basic model cost about $5,000. The first 2200s were shipped in early 1971, and one of them went to a Pillsbury chicken-processing plant in El Dorado, Arkansas. Poor called a technician there to see how the machine was working out. Since normal telephone lines were not reliable enough for transmitting data, he asked what kind of connection the out-of-the-way plant was using to link its terminal to the mainframe, presumably at corporate headquarters in Minneapolis.

"None," replied the technician. He had read through the terminal's documentation and written a payroll program on the 2200 itself, using machine language. The only mainframe connection was the post office; data was periodically output onto cassettes and mailed to Minnesota. Other buyers were applying the Datapoint to accounting and process control; in fact, few of the machines were being used for the purpose they'd been designed for. Desktop computing had been born—brought into existence by resourceful users, not computer designers or marketers.

Meanwhile, TI and Intel belatedly came back with their chips, but CTC was no longer interested. Intel added the chip it had designed for CTC to its catalogue, naming it the 8008. A later upgrade, the 8080, formed the heart of the Altair and IMSAI computers of the mid-1970s; a further modification, the 8088, was used in the first IBM PC. It was followed by the 80286, the 80386, the 80486, and the Pentium—the PC revolution's chip dynasty. If you are using a PC, you are using a modernized Datapoint 2200.

The versatile Frassanito has since worked for NASA and designed the SaniFresh soap dispenser. Poor has retired; Roche died in 1975 and Ray in 1987. CTC became Datapoint Corporation in 1972 and pioneered office automation, inventing the local area network in 1977. Through the 1970s it continued to use in-house upgrades of the 2200's processor boards instead of Intel's chips. In the 1980s, however, Datapoint could not compete with the PC market and was nearly devoured by its own offspring. Today it mainly sells video teleconferencing systems.

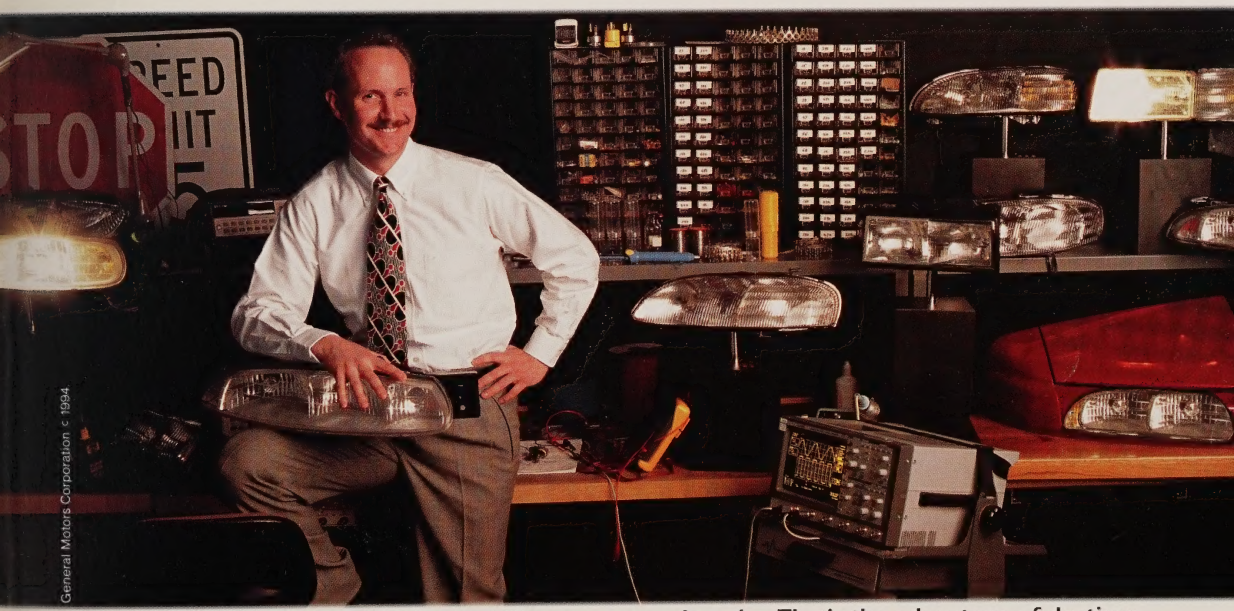
As Frassanito observes, "Pioneers get arrows." ★

Lamont Wood is a freelance writer in San Antonio, Texas.

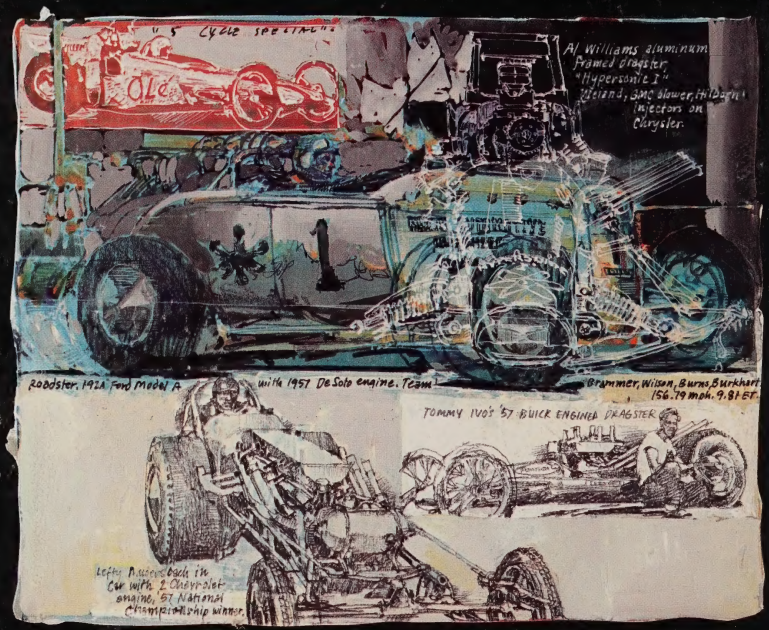
COLLECTION OF BRENDA RAY

General Motors.

"Some of our best ideas even help people who don't drive GM cars."



Soon it will be easier to avoid General Motors cars and trucks. That's the advantage of daytime running lights, according to Joe Griffin, lighting engineer at General Motors Inland Fisher Guide division. Daytime running lights are special headlights that come on whenever you start your engine. Cars that have them are often easier to see, and that can help other drivers avoid collisions. This fall, General Motors will be the first automaker to offer low intensity daytime running lights as standard equipment on thousands of its U.S. cars and trucks. They could make your time on the road safer, even if you don't drive a GM vehicle.


"S CYCLE SPECIAL"
Al Williams aluminum framed dragster "Hypersonic I" Hilborn injectors on Chrysler.
Roadster. 1928 Ford Model A with 1957 DeSoto engine. Team
Brammer, Wilson, Burns, Burkhart 156.79 mph. 9.81 ET.
TOMMY IVO'S '57 BUICK ENGINED DRAGSTER
Lefty Rausenberger's car with 2 Chrysler engine, '57 National Championship winner.

Drag racing began in the late 1940s as a semilegal obsession for hot-rodding California teen-agers; today it's a huge sports entertainment industry and one of technology's most spectacular manifestations. Robert C. Post of the Smithsonian Institution has written a comprehensive history of the sport, from the standpoint of both a fan and a scholar. Here, impressions of drag racing inspired by Post's book, by the artist Barron Storey; for more on the book, see page 6.